1-1-2000

Effects of composts on tomato growth and soil fertility.

Yifan Hu
University of Massachusetts Amherst

EFFECTS OF COMPOSTS

ON TOMATO GROWTH AND SOIL FERTILITY

A Dissertation Presented

by

YIFAN HU

Submitted to the Graduate School of the
University of Massachusetts Amherst
In Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

September 2000

Plant and Soil Sciences

EFFECTS OF COMPOSTS

ON TOMATO GROWTH AND SOIL FERTILITY

A Dissertation Presented

by

YIFAN HU

Approved as to style and content by:

Allen V. Barker, Chair

Douglas A. Cox, Member

Arthur I. Stern, Member

William J. Bramlage, Head

Plant and Soil Sciences

DEDICATION

To my parents and all my family.

ACKNOWLEDGEMENTS

It would not have been possible to complete this study without all the support and encouragement from many people. I would like to thank Dr. Allen V. Barker, my academic advisor, for his terrific teaching, his encouragement, and all kinds of support, especially both his profound academic and unselfish personal support throughout many years of this study. I also would like to thank Dr. Douglas A. Cox and Dr. Arthur I. Stern, my committee members, for their excellent teaching, and personal and academic support.

I would like to thank Dr. Wesley R. Autio, for his wonderful teaching and personal support, also his suggestions and assistance regarding statistical analyses and help in presenting this study. I would like to thank Dr. Steven Herbert, for his great teaching. I would also like to thank Ms. Kathleen Ready for her assistance and friendship. Her help and friendship has been an important contribution to the completion of this study. I would like to thank Ms. Sarah Weis for her great help in atomic absorption analysis, and Ms. Tara O'Brien for providing related data.

Special thanks are due to Dr. William J. Bramlage for his personal and financial support, Dr. William A. Torello and Dr. Ronald Lavigne for their financial and personal support.

Many more thanks must be given to Dr. Allen V. Barker, his professional and very talented editing skills and thorough corrections has made it possible for this dissertation to arrive at its current level.

ABSTRACT

EFFECTS OF COMPOSTS ON TOMATO GROWTH AND SOIL FERTILITY

SEPTEMBER 2000

YIFAN HU, B. S., CENTRAL CHINA AGRICULTURAL UNIVERSITY

M. S., CENTRAL CHINA AGRICULTURAL UNIVERSITY

Ph.D., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Allen V. Barker

This study worked with tomato plants, one soil and one peat moss, and three different composts, addressing the effects of composts and their combinations with soil and peat moss on tomato growth and soil fertility, and reduction of phytotoxicity of immature compost caused by high NH_4 content.

Different composts affected tomato growth differently due to nutrient differences existing among the composts. The higher the nutrients content the better the growth. Using peat moss greatly promoted tomato growth through fertilization and increased nutrient accumulations in plant leaves and soil nutrient residual availability, but this effect was limited to compost containing high content of nutrients. Under normal fertilization practice, each of the various plant growth indices showed highly correlated relationship with total plant dry weight, thus some of the growth indices, such as numbers of plant leaf and flower, could be used to predict tomato production without undertaking destructive harvest. Also each of the major plant nutrients accumulated in plant leaves showed a highly correlated relationship with total plant dry weight.

The maturity of compost was an important factor in assessing the effects of composts on tomato growth and soil fertility. Plants growing in the mature compost medium beneifited from fertilization with nitrate, using NO_3 nutrient greatly increased plant growth and nutrient accumulations in plant leaves and also increased soil K residual availability. Plants growing in the immature compost medium benefit from fertilization with K, using K nutrient tremendously increased plant growth and nutrient accumulations in plant leaves. Immature compost was improved in their capacities to increase plant growth if additional K fertilization was provided. Fertilization with adequate dosage of K was a very effective method to reduce phytotoxicity caused by high content of NH_4 in immature compost. The proper dosage set by this research was 0.6 g K/kg media. The effects on accumulation of nutrients in plants and nutrient residual availability in media were complex and were related to factors such as total plant growth and interactions of nutrients with one another with respect to availability for absorption by plants.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER 1

GENERAL INTRODUCTION

1.1 Literature Review

Composts are products from the practice of employing biological reduction of organic wastes into humus or humus-like materials that benefit soil and environment. Composting has been used to transfer sewage sludge, household garbage, organic trash, food processing wastes, and farm manure, into soil amendments or fertilizers suitable for application to agricultural lands and horticultural gardens (Stratton, et al., 1995).

As a waste management practice, composting of different sources of waste materials has been conducted successfully for many years. However, the uses and real values of composts have been recognized only recently. Soil fertility is mainly dependent on organic matter content and other soil properties. By applying high quality composts, along with reduced amount of chemical fertilizers, high crop production and maintenance or even increase of soil fertility can be expected. The application of composted materials rather than raw wastes is a better practice, because composting raw wastes can eliminate or greatly reduce adverse of insects, various disease sources, and weed seeds.

The most commonly composted materials include municipal solid waste (MSW), sewage sludge (SS), vegetative wastes such as yard waste, lawn trimmings, and kitchen vegetable scraps, farm manure, and wastes from food processing industries. Most of the materials are easily breakable. Composting of biosolids, municipal solid wastes, and farm manure is an effective means of reducing or stabilizing wastes before application to agricultural lands and horticultural gardens.

1.1.1 Compost Properties

Macro- and micro-nutrients and organic materials in composts improve soil chemical properties such as nutrient contents, and pH environment; physical properties, such as water retention, tilth, and porosity; and biological properties such as microbial activities, suppression of soil-derived diseases.

Physical and chemical properties of compost are very important regarding its uses and values. Physical properties mainly affect soil bulk density, porosity, and water holding capacity. Chemical characteristics majorly control nutrient availability and influence environmental quality. Biological properties principally influence plant disease control, and also environmental properties.

1.1.1.1 Physical Properties

Physical Properties, including porosity, bulk density, water content, particle size, texture, color, weed seed content, and content of inert material such as glass and plastics, are major concerns to compost users. Among those properties, water content, texture and color may be the practical standards for most customers. Most consumers expect compost to be dark brown colored with a loamy texture (Buhr, et al., 1993).

In general, fine-textured composts are more desirable for soil mixes for garden use and residential lawns and gardens, and coarse-textured composts are economical and suitable for mulches, agriculture, and land reclamation. The acceptable moisture content of compost is in the range of 30 to 60% by weight. Below 30%, the material becomes dusty, and above 60%, the texture and appearance become less attractive, and introduce trouble for spreading and potential of bad odor production (Brodie, et al., 1994).

1.1.1.2 Chemical Characteristics

The principal value of compost is its ability to supply organic matter. Compost organic matter can provide important soil conditioning benefits (Arkin, and Taylor, 1981). These benefits include the followings: Enhancing aggregation; Increasing soil aeration; Lowering bulk density; and Increasing water infiltration and water holding capacity.

The organic matter content of compost is a major factor for compost use, and the mineral nutrient contents are also important. The composition of N, P, K, Ca and Mg of composts varies depending on the source of the wastes. However, compost typically contains (dry weight base) about 0.5 to 3.0% N, 0.5 to 3.0% P_2O_5, 0.2 to 2.0% K_2O, 0.5 to 5% Ca, and 0.1 to 3% iron (Naylor, 1996). In addition, most compost contains variable amounts of other macronutrients, such as Mg and S, and micronutrients, such as B, Cu, Mn, Mo, and Zn.

The total and extractable nutrient analyses provide reasonable estimates of the nutrients in compost for the long term and the short-term uses. Results from many studies on composts suggest that about 10 to 15% of the organic N are released during the growing season. The residual N remains in the soil and continues to provide N for plant growth for several years.

The plant nutrients tend to be released gradually in response to the conditions that also control plant growth, the conditions include moisture, pH, light, and temperature. Because of this slow release nature, it tends to result in more efficient use of the nutrients, and reduce nutrient loss by leaching.

1.1.1.3 Specific Parameters Concerning Compost Use

Specific parameters typically include pH, soluble salts, organic matter content, C:N ratio, heavy metals, and weed content.

Soil pH is important because it affects the availability of trace mineral elements, the activity of microorganisms, so the availability of some macroelements to plant, and also affects plant resistance to diseases. Depending on the properties of raw materials and the amendments added, compost can have pH ranging from 5.0 to 9.0. Many soils have high buffering capacities, and common dosage of compost do not change the pH measurably (Naylor, 1993).

Lower pH increases the solubility of Al, and micronutrients such as Fe, Mn, Zn, Cu, and macronutrients such as Ca, K, Mg, and P. For ericaceous plants such as azaleas, gardenias, rhododendron, or laurel, a growing medium pH of 4.5 to 5.5 is desired. On the other hand, nonericaceous plants grow best in medium pH of 5.5 to 6.8. Most composts have a pH of 6.8 to 7.5.

The amendments, such as lime (CaO, $CaCO_3$) or alum [$Al_2(SO_4)_3$] used in compost processing, may affect its market value because of the effect of these constituents on the final compost pH, color, texture and inert content. Blending high-pH compost with oak leaves, pine needles, or sphagnum peat has been suggested as a means of lowering the final product pH.

Some biosolids used to produce compost are rich in soluble minerals such as Ca, Mg, Na, sulfates, and chlorides. Although those minerals are essential or beneficial for plant growth, excess content can damage plant roots and inhibit germination, especially for container crops. Extreme high concentration of soluble salts can be harmful to plants, causing leaf burn, chlorosis, wilting, and eventually lower yields. By providing adquate drainage, high soluble salts in compost usually is not a problem for users.

The heavy metal content is a major concern of compost use. Pretreatment programs have dramatically lowered the metal content of biosolids.

Many of the regulated heavy metals are actually micronutrients that are essential for plant growth. By keeping compost within the U.S. EPA limits, heavy metals such as Pb and Cd are not a threat to the public.

The C to N ratio of compost indicates the maturity of compost. The C:N ratio should be in the range of 15 to 25. Additional soluble or readily available N should be added to a growing medium to prevent N deficiencies when immature compost is used.

Weed seeds in compost used to be a problem to compost users. The compost facility will effectively destroy weed seeds if the processing time and temperature are appropariate. Also it is important to protect the compost from being infested with wind-blown weed seeds during storage or curing. Protection can be achieved by covering the material or piling the compost and allowing it to reheat and destroy the weed seeds.

1.1.2 Compost Utilization

Using compost as soil amendments for general landscaping and gardening, land reclamation, top dressing on turf, agricultural soil amendment, depressing weeds, erosion control and many others is getting more and more popular.

Public concerns for using compost include heavy metals, organic and inorganic toxins and contaminants in composts; all kinds of pathogens. All of pathogen organisms and other unfavorable components are potentially present in municipal wastewater sludge. Various regulations on these aspects have been carried out for many years, and where these regulations have been followed, pathogens and other harmful components can be effectively eliminated from composted biosolids.

Many comparison studies of applications of commercial fertilizer with compost show significantly higher yields and better growth and matainance or increase of soil fertility.

1.1.2.1 Composts Used as Landscape Soil Conditioner

Using compost as a soil conditioner is a high-quantity, low-value application of composts. Application of organic matter will improve soil structure and other soil conditions for plant growth. Some uses include road construction, motorway verges, and surfacing of landfill sites. For this kind application, quality requirements can below. The maturity of the composts may not be that important either. For other utilization of composts, such as parks and gardens, playing fields, and golf courses, glass content should be kept to a minimum and the product should be well sanitized. Again, the maturity of the composts is less important. Some controlled trials on ryegrass has shown that unstable compost is a valuable source of slow-release nutrients, giving consistently high growth rate for at least 6 months after initial application of composts. The total amount of application for these areas can be virtually much higher, since ornamental rather than crop plants are to be cultivated.

Landscape soils are often greatly lack of organic matter, many of them will benefit from addition of composts. Sometimes with a low C: N ratio is needed so that mineralizable N can be made available for plant growth. Other times compost with a high C: N ratio may be preferred so that they remain resistant to breakdown.

Composts may improve a soil as a growing medium through the following actions: crumb forming action (through long chain molecules); flocculating effect (through high calcium content); buffering capacity (improving the CEC of the soil); resource storage capacity (where the compost particles hold water and nutrients, rather than improving the ability of the soil to hold resources); bulking agent (holding open channels in a poorly drained soil without necessarily forming crumbs in the intervening soil mass); humus source (with the associated potential structural and chemical benefits); nutrients; inoculum of beneficial soil organisms; and something related to cultivation rather than directly to plant growth, such as reduction in bulk density or ease of tilth.

Topsoil substitutes are a growing area in landscape work. They are usually created by mixing subsoil of selected texture class with some form of organic waste materials.

Since the cultural requirements of landscape plants, and indeed most crop plants, are not as demanding as container-grown plants. Criteria such as pH, nutrient content and weed content may be defined as meeting a wider acceptable range. Salinity should be more under control in normal field topsoil than in container soil because adquate leaching may be aproblem in some topsoil.

On the other hand, composts may cause some problems in some soils by causing waterlogging, immobilization of available N, oxygen depletion, and poor re-wetting.

1.1.2.2 Composts Used as Mulch

Compost can be used as mulch with the following benefits to soils: Weed control, use of compost can reduce existing perennial weeds, affect existing soil borne weed seed, and affect surface-blown incoming weed seed, provided that the composts do not possess viable weed seed. Better water infiltration and less soil erosion, use of compost makes water from rain and irrigation penetrate soil easily. Reduction in evaporation, use of compost makes it possible to use water more efficiently. Temperature improvement, use of compost can give crop plant better environment to grow.

In Copenhagen, Denmark, composts were used as mulch for road trees. The survival rate and growth of the trees were substantially increased during the following years. Composts were also used as mulch to prevent and control weeds in Denmark (Carlsb(k, and Reeh, 1996). The effect of controlling weeds really depends on the origin of composts. They found that the compost layer must be at least 10-cm thick to give a substantially weed reduction for some species, but 3-cm layer is thick enough to prevent the emergence of smaller-seeded weeds when no viable plant vegetative parts are present. The results are attributed to the covering effect and chemical effect of the compost.

Ignitability is one concern because mulches may be a fire risk. Nitrogen availability is another concern as composts used as mulches are often created from materials that have not been or have been only poorly composted or aged. These composts may cause N immobilization and induce N deficiency. Pathogen content or support is also worrisome since some organic mulch such as wood chips represents a potentially substrate for plant pathogens such as Armillaria. Another concern is the behavior of possible toxins or contaminants in the mulches if they are reachable.

1.1.2.3 Composts Used as Bulky Organic Fertilizers

Composts can be a source of organic matter as well as a source of nutrients. This application requires higher quality with minimal heavy metal contamination. Also, if immature composts are used, it is necessary to wait for some time to allow degradation of phytotoxins that might adversely affect germination of crop seeds. Using composts as a nitrogen source may be very helpful in reducing the nitrate-leaching problem associated with fertilizer use in some areas. Raviv et al. (1986) reviewed the value of composted organic matter in container-growing media. Many of biological properties of organic matter can be attributed to the presence of humic and fulvic acids. In addition, composts appear to supply growth hormones to plants.

Composts as a source of humic material effectively improve soil structure, aeration, and permeability. Application of more easily decomposable organic residues also helps to form humic colloids and crumble soil structures. In poorly structured soils, the ability of plants to take up nutrients can decrease remarkably. Humus, by improving soil structure, increases the ability of soils to resist erosion from wind and water. Composts also enhance the activities of beneficial soil organisms, such as bacteria, fungi, protozoa, and earthworms, by providing the necessary food for them, which in turn help to improve soil structure and increase soil fertility.

Excess use of immature composts or undecomposed organic matter can have harmful effects, such as reduction of nutrient availability due to immobilization especially N, formation of phytotoxins, sustained activities of pests and diseases, and deactivation of agrochemicals such as herbicides.

Avnimelech et al. (1990) investigated the effect of municipal solid waste compost on the fertility of clay soils. Yields of wheat were related to compost application rates up to the highest range of application 212 yd^3/acre ($400m^3$/ha), at that rate a slight suppression in yield was shown. A similar pattern of yield increase was observed with corn, but with no yield suppression at the highest level of application. At the same time, increases in salts, organic carbon, and NH_4 in the soil were observed, but a decrease in

NO_3 concentration was also noted. It was believed that the loss of NO_3 was due to anaerobic conditions and denitrification induced by the addition of organic matter. Decomposition of organic matter at low temperature (in winter) led to the production of simple organic acids, but at high temperatures (in summer), the products were humic substances.. The significant positive effects of the compost application were limited only to a single growing season. It was concluded that a surface application of compost produced and maintained a better aerobic environment and healthier conditions for plant growth and development than other kinds of application.

In addition to replenishing soils with the organic matter, composts provide a wide variety of soil microflora and microfauna that assist to improve soil fertility by increasing the rate of nutrient recycling.

Some data showed that a fresh compost when used as a part of a growing medium possessed a large range of organisms that proliferated (Griffiths, 1989). In the example shown, the fresh compost has undergone exposure to thermophilic digestion but had not stabilized. The 12-week sample had compost incorporated into a grit/sand base and was sustaining the growth of perennial ryegrass. Initially high concentration of amoeba and flagellates fell rapidly, but numbers of both ciliates and nematodes increased. These organisms are involved in N cycling and may improve the availability of N to plants.

In addition to inoculating soil with beneficial microorganisms, compost has the potential to stimulate N-fixing activity. Recent research in Australia has shown that the incorporation of high-carbon residues into topsoil significantly enhances the activity of free-living N-fixing organism such as Azotobacter, Azospirillum, and Klebsiella. Experiments were carried out using straw, which consists of cellulose (32 to 45%), hemicellulose (32 to 34%), and lignin (14 to 17%). The cellulose and hemicellulose are easily decomposable to simple sugars such as glucose and mannose, which N-fixing bacteria can use to provide metabolic energy for N fixation. Peak N-fixing activity was noted at 30 to 45 days following incorporation of straw (Roper and Halsall, 1986). If a soil was fed with glucose directly, nitrogenase activity peaked at 2 days following glucose treatment (Roper, 1985).

Fertile soil is a complex ecosystem with the interactions of many types of soil organisms. Of particular interest are those involved in N cycling. In recent years, interest had been placed on the interactions between bacteria and protozoa. Griffiths (1989) showed that the presence of bacteriophagous protozoa increased nitrification by stimulating the release of NH_4^+ and NO_3^- from the bodies of bacteria. It is reasonable to expect that some composts at least will be able to stimulate N fixing through the supply of energy-rich compounds and action of bacteriophagous protozoa (ciliates).

1.1.2.4 Composts Used in Horticulture as Growing Media

In this kind of application, composts may be valuable as an alternative to peat moss as a growing media component. For this application, maturity, hygiene and absence of glass are most important factors. The physical form of glass is more important than the absolute content. Numerous growing trials have been carried out to use refuse-derived composts and have shown better long-term results than more conventional or peat-based media do. Trials have also demonstrated that a low percentage of unstable compost (20% by volume) can result in better long-term growth than using conventional inorganic fertilizers. Immature composts can promote better growth than stable composts over the long term if used properly. A current problem with using immature composts for ornamental plants is the development of fungal growth and infection with fruit flies. The density of composts is usually sufficient to support plants growing in it. They are sterile containing no plant or human pathogens and no weed seeds or insect pests. Most compost is neutral or has a low pH.

However, regular materials derived largely from the aerobic breakdown of organic materials do not generally possess the same characteristics as other materials often used in horticulture. Although aeration and water holding capacity can be good, these kind of composts often have a high content of available nutrients and also contain other salts which can cause them unsuitable for many horticultural compost applications such as seed raising. Significant nutrients release, associated with continued decomposition once they are incorporated in growing media, is usually undesirable for some horticultural needs. Decomposition is associated often with loss of bulk, leading to shrinkage that is not good for some horticultural usage such as hardy nursery stock production. However, this kind of loss may be unimportant in short-term applications of compost as horticultural media, such as transplantation and production of bedding plants.

Some positive and negative examples have been recorded concerning growth of bedding plants in compost-amended soils. Composts for bedding plants should be free of weed seeds. The bedding plant, Impatiens spp., grew well in pure, 0 to 10 mm screened 1-year-old garden and park waste compost. In another example, bedding plants were scorched when 3 cm of 1-year-old nutrient-rich compost was mixed 5 cm into the topsoil before transplanting. Propagation of bedding plants and shrubs in a 1:1 volume mixture of peat and garden and park waste compost failed when the potted plants were removed outdoor for hardening. The growth medium did not drain properly during periods of rain, so that eventually planting out was difficult because of the muddy structure of the compost. Growth trials with nursery plants in containers where 25 to 50% volume of compost was mixed with peat showed negative responses including increased conductivity, increased pH, possible N immobilization, and reduced water-holding capacity compared with peat alone. Phosphorus, Fe or Mn deficiencies might be induced when pH is above 7.

Composts for horticultural use can be classified into some special categories: Seed composts, which are generally finer in texture than general potting composts, with lower nutrient content, low salinity but are also intended for relatively short-term use where issues such as stability of structure may not be important. Plug composts, which are a relatively specialized form of media where individual plants are grown in cells that have extremely low volume. Blocking composts, which have a relatively fine texture and internal cohesion force, allow plants to grow in shaped media without pots. Ericaceous composts, which are specially prepared to meet the need of low pH environment.

Because many kinds of composts have their tendency to lose structure quickly, they are used primarily for short-term crops and seed composts.

1.1.2.5 Composts Used in Disease Control

Compost has been suspected by organic gardeners and is now being proven to have the ability to control plant pathogens. Hornick et al. (1983) reported that composts controlled some root rot and other plant pathogens, and plant nematodes would also be controlled. Kuter et al. (1983) found that specific fungal populations colonizing compost were responsible for suppression of rhizoctonia damping-off. Nelson (1992) continued this work focusing on pythium blight and dollar spot control on turf and found that bacterial populations can also play an important role in controlling plant pathogens. Hoitink, Boehm, and Hadar (1993) reviewed some of current understanding of the widespread mechanisms of disease suppressing effects by compost.

Plant pathogens are effectively destroyed by the thermophilic phase of composting (Hoitink et al., 1994). In addition, when composts are added to other substrates such as soil, spores of pathogens (e.g. pithium and phytophthora) are prevented from developing by general suppression. This suppression is due to the high populations and biological activities of other native microorganisms. Biological control of "damping off" pathogens (e.g. rhizoctonia) may also be achieved by adding composts, but it is important to ensure that the composts possess a high microbial species diversity. The pathogen-suppressing effects of composts can be limited by its chemical properties. For example, composted municipal sludge with a salinity of higher than 10 mS cm^{-1} can increase root rot in beans. In general, the pathogen-suppressing qualities of composts are hard to predict. Maximal disease suppression occurs in partially but not fully matured compost products. Composts and some soil amendments can increase total microbial activity and populations of certain microbial functional groups, some of them are negatively correlated with some disease incidence and severity (Kim, et al., 1997, Ringer, et al., 1997). Composts were proven to be suppressive to Pythium damping-off and root-rot, and the suppressive extent was connected with their organic matter content (Erhart, and Burian, 1997, Mandelbaum, and Hadar, 1997). There was evidence that low levels of NO_2- or NO_3-N were associated with suppression of Pythium damping-off (Ringer et al., 1997). Other research has shown that compost can induce cucumber (*Cucumis sativus* 'Straight Eight') to resist to pythium root rot and anthracnose (Zhang, et al., 1996).

Composts can be used to effectively control root-knot nematodes in tomato and pepper (Marull, et al., 1997). Applying composts to soil generally decreases herbicide mineralization and helps to stabilize the herbicide residue (Barriuso, et al., 1997).

1.1.2.6 Composts Used for Erosion Control

In a simulated experiment, two composts (28 or 34% of organic matter by weight) were added to a soil, then compared at flat or a regular pattern of ridges of the soil surface with untreated soil. The results showed that the wind erosion was greatly reduced on compost-amended soil (Decos, 1996).

1.1.3 Compost Quality Check

A number of criteria have been suggested and used as guidelines for compost quality control. Relevant criteria that have been proposed by experts and regulators (Forste, 1996, De Bertholdi, et al., 1990, and Manser, and Keeling, 1996) include:

Organic matter and total nitrogen content, and C:N etc.

Moisture content. Lower moisture content helps in spreading and storage operations. Also, relatively dry material (25% moisture or less) is desirable for bagging, since it is less likely to become moldy or malodorous.

Inert material content. They include glass and plastic, and particulate metal. The physical nature of the inert material is important. In general, the smaller the particle size, the less the effect on the appearance of the product and on its use.

Nutrient content. The minimum content for land incorporation should be as follows: N-0.6%; P_2O_5-0.5%; K_2O-0.3%; CaO-2.0% (or $CaCO_3$-3.0%); MgO-0.3%.

Salinity. Very high salinity can damage crops, particularly in calcareous soil. A salinity level should be below 0.2 oz/ft^3 (2g/l) salt (expressed as NaCI). The harm caused by high salinity is dependent on the amount of compost to be used in a given application and specific plants. Growth trials should be used to determine the maximum application rates.

pH. Compost pH values between 5 and 8 are acceptable for plant growth. These levels will not affect soil pH appreciably. pH is also an indicator of maturity.

Heavy metals and other toxic element. They are often present in unacceptably high levels in composts even though many of them are vital trace elements for plant growth, especially if the compost is derived from refuse or sewage sludge. The proposed limits of metal contents in compost are suggested as (mg/kg): Zn-2800; Pb-300; Cu-1500; Cr-1200; Ni-420; Hg-17; Cd-39; As-41; Se-36 (Forste, 1996). The figures given here are the recommended limits for compost to be used for growing ornamental, and the maximum concentrations in sewage-sludge-treated agricultural soil. Compost with high levels of metals may be used in a range of applications provided the total final metal concentrations recommended are not exceeded.

1.1.4 Compost Maturity

Composting is characterized by a high degree of initial microbiological activity, which gradually declines as most available carbon and other nutrients are used up by microbes. Compost showing a low biological activity is considered mature. Compost should be well-stabilized and mature prior to applications since unstable or immature compost may contain or produce toxic substances to plants.

Phytotoxicity of immature composts has limited the potential use of different composts worldwide. When immature compost is introduced to plant root, root damage may occur. The injury and inhibition can be attributed to the phenols, low weight organic fatty acids, high C:N ratio, and high NH_4 content (Wang, et al., 1967, Chandrasekaran et al., 1973, and Findenegg, 1987). Some studies have attributed phytotoxic effects to high ionic strength or pH imbalance (Shiralipour, et al., 1997). Seed germination and seedling growth were strongly inhibited by immature compost and manure (Maureen et al. 1982). Use of immature compost resulted in considerably lower yield compared with inorganic fertilizer and mature compost treatments (Chanyasak, et al 1983). Some research indicated that water soluble C:N, humic: fulvic acid, and CEC were not suitable as an indicator to predict biomaturity in terms of growth enhancement and lack of phytotoxicity (Erhart, et al., 1997). If compost is not matured, its application can result in delay, inhibition or suppression of seed germination and plant growth. An investigation indicated that the inhibitory effect of acetic acid on seed germination and root elongation suggested a metabolic phenomenon (Shiralipour, et al., 1997).

No single procedure can be applied to all composts for determining maturity. Using cress germination assays, the simplest test, may be more appropriate for routine local testing. Assessment of maturity is not easy because of little understanding of the related processes. However, some methods have been used (Inbar, et al., 1990).

1. Carbon-based analysis. This involves measurement of organic matter levels and C:N ratios. Some research indicated that the C:N ratio is not good indicator for maturity.

2. Humification indicators. Measurements of humic substances in a compost may provide an effective measurement of maturity, especially humic acids (HA) carbon to fulvic acid (FA) carbon ratios. HA content rises as compost proceeds mature.

3. Molecular size determinations. Molecular sizes increase as humic substances are formed, but will vary depending on the nature of the incoming organic material.

4. Enzyme assays. Enzymatic activity changes during the composting process, e.g., alkaline phosphates, inverters, hydrolyze, and protease, but how to use this method to measure the maturity needs more research.

5. Respiration measurements. There is a fall in respiratory activity as compost becomes mature. It has been proposed that compost may be considered mature when its oxygen consumption is less than 0.0006oz/lb. (40 mg/kg) dry matter per h at 20^{o} C.

6. Phytotoxicity assays. During the anaerobic composting process, a number of substances are generated that may be harmful to plant growth. The most abundant phytotoxics tend to be low weight organic acids, especially acetic, proprionic, butyric, and valeric acids, and aromatic compounds such as phonetic acids. The presence of phytotoxicity may be assessed using cress seed emergence tests. Initial studies of unstable and stable composts suggest that stable composts contain very few low molecular weight components and this may be a useful indicator of maturity.

1.2 Research

1.2.1 Justification

Composting different wastes have been increasingly recognized as a promising option to waste management. The chemical, physical and biological properties of MSW, sewage sludge, and other waste composts and their effects on soil properties have been studied extensively. Compost utilization has been studied broadly. Several criteria have been suggested and used for compost quality control especially for assessment of maturity. Little literature compares composts with each other for crop plants, and how composts affect plant growth even though much research addresses plant growth in individual composts. Also very little literature addresses how to eliminate or reduce phytotoxicity of immature compost. The wide C:N ratio, high NH_4 content, and some phytotoxins such as phenols and low molecular weight organic acids can induce phytotoxicity to crop plants. This study worked with tomato plants, three different composts, one soil and one peat moss, addressing how composts and combinations of different materials affected tomato growth and soil fertility, and how phytotoxicity of immature compost caused by high NH_4 content could be reduced or eliminated.

1.2.2 Objectives

1. Assess the effects of different composts and their combinations with other materials on tomato growth and soil fertility.

2. Compare mature compost with immature compost, and find a practical means to avoid or reduce phytotoxicity of immature compost caused by high NH_4 content.

1.2.3 Experiments

1.2.3.1 Experiment 1: Effects of Composts and Their Combinations with Other Materials on Tomato Growth and Soil Fertility

This experiment was designed to assess the effects of composts and their combinations with soil and peat moss on tomato growth and soil fertility.

Composts from sewage sludge, yard waste, and agricultural sources were used. Those materials are major sources of composts on the market. Tomato (Lycopersicon esculentum Mill.) plants were employed as an indicator crop. This was because it is an important vegetable crop with high market value, and its nutritional characteristics have been studied extensively throughout the world especially at University of Massachusetts (Barker, et al. 1986, Barker, 1976, Barker, et al. 1994, Corey, et al. 1989, Feng, et al. 1992). Different combinations (regimes) of composts and other media (soil and peat) were chosen as (1). Compost alone without amendment (C), (2). Compost and soil at ratio of volume of 1:2 (CS), (3). Compost and peat moss at ratio of 1:2 (CP), and (4). Compost and soil and peat moss at the ratio of 1:1:1 (CPS) in order to find optimum combinations that benefit tomato growth and soil fertility. Tomato grew for a certain time in a greenhouse from seedlings until fruit initiation. The content of N, P, K, Ca, and Mg of compost was measured before setting up the experiment (Table 1.1). Soil samples was taken after harvest for N, P, K, Ca, and Mg measurement to assess changes in nutrition availability during the experiment. At harvest, growth indices including plant height, number of flowers, number of fruits, number of leaves, and fresh weights of fruits, leaves, and stems were recorded. Dry weights of fruits, leaves, and stems were also recorded. Dry leaf samples of were prepared after harvest for nutrient analysis of N, P, K, Ca, and Mg. Nutrient content of N, P, K, Ca, and Mg accumulated by tomato was used to assess acquisition of nutrients from the media. Criteria for evaluating effects of composts and their combinations on tomato growth and soil fertility would be tomato growth indices, total nutrient accumulations, and soil nutrient availability.

1.2.3.2 Experiment 2: Reduction of Phytotoxicity of Immature Compost

This experiment was designed to find practical ways to avoid or reduce phytotoxicity of immature composts caused by high NH_4 content.

Uses of immature composts are often difficult due to high NH_4 content. NH_4 toxicity is common in immature composts made from N-rich substances. This research was focusing on the toxicity caused by high NH_4 content because of its prevalence, its phytotoxicity at high concentration, its indication of compost immaturity, and ease of determination. A compost of biosolids and wood chips was treated with $(NH_4)_2SO_4$ to 2,000 mg N kg^{-1} to simulate an immature compost. Use of synthetic immature compost instead of a natural one was for quality control since as mentioned before so many factors can attribute to immaturity of composts, and NH_4 can vary with time and handling in storage. Previous research has shown that 2,000 mg NH_4^+-N kg^{-1} is a common concentration in fresh immature compost. The same compost without any ammonium added was used as mature compost. In both composts, different proportions (regimes) of compost and soil was used at the ratios of 1:2, 1:5 and 1:11 by volume to find a combination good for tomato growth without any irretrievable damage. Each regime received potassium treatment at 0 or 0.6 g K kg^{-1} medium as KCl, based on previous research that K has an ability to alleviate NH_4 toxicity by antagonism and promoting NH_4 assimilation. A nitrate treatment at 0 or 2,000 mg N kg^{-1} compost as $Ca(NO_3)_2$ was used, based on the fact that nitrate has been reported or suspected to lessen toxicity of NH_4. Tomato grew from seedlings until fruit initiation. The growth indices such as plant height, number of flowers, the number of fruits, number of leaves, and fresh weights of fruits, leaves, and stems were recorded at harvest. Dry weights of fruits, leaves, and stems were also recorded. Growth indices were used as criteria for evaluating the method to reduce the phytotoxicity caused by high NH_4 content. Dried leaf and soil samples were prepared for N, P, K, Ca, and Mg analysis. The analysis was used to help to evaluate the method of elimination or reduction of phytotoxicity of immature compost.

1.2.3.3 Experiment 3: Effects of Different Dosages of K on Tomato Growth and Soil Fertility

This experiment was designed to find an appropriate dosage to effectively avoid or reduce phytotoxicity of immature composts caused by high NH_4 content.

A compost of biosolids and wood chips was treated with $(NH_4)_2SO_4$ to 2,000 mg N kg^{-1} to simulate an immature compost. As discussed above, use of synthetic immature compost instead of a natural one was for quality control since as mentioned before so many factors can attribute to immaturity of composts, and NH_4 can vary with time and handling in storage. Previous research has shown that 2,000 mg NH_4^+-N kg^{-1} is a common concentration in fresh immature compost. The same compost without any ammonium added was used as mature compost. In both composts, different proportions (regimes) of compost and soil were used at the ratios of 1:2 and 1:11 by volume to find a combination good for tomato growth without any irretrievable damage. Each regime received potassium treatment at 0, 0.3, 0.6 and 0.9 g K kg^{-1} medium as KCl, based on previous research that K has an ability to alleviate NH_4 toxicity by antagonism and promoting NH_4 assimilation. Tomato was allowed to grow until fruit initiation. The growth indices such as height, number of leaves, flowering time and number during the growth, the number of fruits and fresh weight were recorded at harvest. Growth indices were used as criteria for determine the appropriate dosage. Dried plant and soil samples were prepared for N, P, K, Ca, and Mg analysis. The analysis was used to help to find the appropriate dosage to eliminate or reduce phytotoxicity of immature compost.

Table 1.1 Selected Nutrient Contents of Tested Composts

Composts	Nutrient Elements				
	N	P	K	Ca	Mg
	%				
AW	1.5	0.81	0.50	2.55	0.44
SS	0.8	0.12	0.20	1.13	0.35
YW	0.7	0.16	0.26	1.90	0.60

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; and YW= Yard Waste Compost.

CHAPTER 2

EFFECTS OF COMPOSTS AND THEIR COMBINATIONS WITH OTHER MATERIALS ON TOMATO GROWTH AND SOIL FERTILITY

2.1 Introduction

Composting of different wastes has been increasingly recognized as a promising option to waste management (Goldstein, 1989; Glenn and Riggle, 1991; Airan and Bell, 1980; De Haan, 1981; Finstein and Miller, 1985; He, et al., 1995; Richard and Chadsay, 1990; Terman and Mays, 1973). It bas been believed that by applying good composts supplemented with lower amount of chemical fertilizers, high crop production and maintenance or even increasing soil fertility can be achieved. It has been commonly accepted that the application of composted materials rather than raw wastes to land is a better practice, because raw wastes can be contaminated with insects, various disease sources, and weed seeds. And it has been favored that composting of biosolids, municipal solid wastes, and farm manure is an effective means of reducing or stabilizing wastes before application to agricultural lands and horticultural gardens.

The chemical, physical, and biological properties of municipal solid waste (MSW), sewage sludge (SS), and other waste composts have been studied extensively (Fricke and Vogtmann, 1994; Diaz-Ravina, et al., 1989; Elnadi, et al. 1995; He, et al., 1992; Villar, et al., 1993). The effects of different composts on soil properties have been studied extensively (Ahrens and Farkasdy, 1969. Andersson, 1983. Bengston and Cornette, 1973. Canarutto, et al., 1991. Giusquiani, et al., 1995. Paino, et al., 1996. Serra-Wittling, et al., 1996. Buchanan and Gliessman, 1991. Pagliai, et al., 1981. Hernando, et al., 1989. Godden, et al., 1987). Physical and chemical properties of compost are very important regarding its uses and values. Physical properties mainly affect soil bulk density, porosity, and water holding capacity. Chemical characteristics primarily control nutrient availability and influence environmental quality. Biological properties principally influence plant disease control, and also environmental properties. Macro- and micro-nutrients and organic complex in composts improve soil chemical properties such as nutrient contents, and pH environment; physical properties, such as water retention, tilth, and porosity; and biological properties such as microbial activities, suppression of soil-derived diseases. Every aspect can affect the soil properties and plant growth when a compost amendment is used.

Compost utilization has been also studied broadly (Rosen, et al., 1993. Gouin, 1993. Logsdon, 1993. Gamliel and Stapleton, 1993. Hoitink, et al., 1993. Werf, 1993. Rich and Hodge, 1993. Kapetanios and Loizidou, 1992. Cisar and Snyder, 1992. Nelson and Craft, 1992. Hadar, et al., 1992. Lamanna, et al., 1991. Schueler, et al., 1990. O'Brien and Barker, 1995 and 1996. Malone, et al., 1996. Sann, 1995. Cole, et al., 1995. Henry and Bush, 1996. Peot and Thompson, 1996. Roe, et al., 1993. Garland, et al., 1995. Diez, et al., 1995. Brietenbeck and Hallmark, 1993). Using compost as soil amendments for general landscaping and gardening, land reclamation, top dressing on turf, agricultural soil amendment, depressing weeds, erosion control and many others is getting more and more popular. Public concerns for using compost include heavy metals, organic and inorganic toxins and contaminants in composts; primary pathogens, secondary pathogens including fungi and molds, salinity effects, and plant pathogens. All of those pathogen organisms and other unfavorable components are potentially present in municipal wastewater sludge. Various regulations on these aspects have been carried out for many years, and where these regulations have been followed, pathogens and harmful components have been effectively eliminated from composted biosolids. Many comparison studies of applications of commercial fertilizer with compost show significantly higher yields and better growth for compost-amended soils. The organic matter in the compost improves the soil physical properties, including enhanced aggregation, increased soil aeration, lower bulk density, less surface crusting, increased water retention and content, and improved infiltration. In clay soils, compost has shown to reduce compaction and increase root development and depth. Compost-amended soils tend to help plants resist some diseases and pests such as nematodes.

However little literature compares composts with each other for crop plant, and how composts affect plant growth even though much research addresses plant growth in individual composts (Madejon, et al., 1995. Paino, et al., 1996. Berner, et al., 1995. Hountin, et al., 1995. Ozores-Hampton, et al., 1994. Maynard, 1995. Ashley, 1993. Manios and Kapetanios, 1992. McConnell, et al., 1991). The fitness of composts for tomato growth was addressed in this research. This study worked with three different composts and other materials including soil and peat moss for the purposes of assessing effects of different composts and their combinations with soil and peat moss on tomato growth and soil fertility.

Agricultural waste (AW), sewage sludge (SS), and yard waste (YW) are major sources of composts on the current market. Tomato has been an important vegetable crop with high market value, and its nutritional characteristics have been studied extensively throughout the world, especially at the University of Massachusetts Amherst (Barker, 1976; Barker et al., 1994; Barker et al., 1986; Corey et al., 1989; Feng et al., 1992).

2.2 Materials and Methods

2.2.1 Materials

Composts made from agricultural waste (AW), sewage sludge (SS), and yard waste (YW) were used. A soil and peat moss were also used as part of culture media. Tomato plants (Lycopersicon esculentum Mill.) were employed as an indicator crop.

2.2.2 Methods

Four different combinations (regimes) of composts and other media (soil and peat moss) were chosen. They were compost alone (C); volumetric ratio of compost and soil at ratio of 1:2 (CS); compost and peat moss at ratio of 1:2 (CP); and compost and soil and peat moss at the ratio of 1:1:1 (CPS). The purpose of the use of different regimes was to find optimum combinations that benefit tomato growth and soil fertility. The tomatoes grew in a greenhouse for about 6 weeks from seedlings to fruit initiation. Each regime carried a fertilized treatment and a non-fertilized treatment. The fertilized treatment consisted of using 0.15 g N, 0.15 g P_2O_5, and 0.15 g K_2O per kg media from a 20-20-20 formula commercial fertilizer (Peters, General Purpose Fertilizer, Fogelsville, Pa.). The fertilizer was applied three times at the amount shown above with interval of two weeks after tomato seedlings were planted.

The contents of N, P, K, Ca, and Mg in the composts were measured before setting up the experiment (See Table 1.1).

Soil samples were taken after plant harvest for N, P, K, Ca, and Mg measurements to assess the effects of the treatments on soil nutrient availability. A method proposed by Morgan (Morgan, 1941) was used to extract soil nutrients. Nitrogen was determined by distillation and titration of NH_3 in solution (Bradstreet, 1965); P was determined by colorimetry (blue molybdophosphoric acid method, Olsen and Dean, 1965); Ca and Mg were determined by atomic absorption spectrometry; and K by atomic emission spectrometry (Thomas et al., 1967; Lierop, 1976). At harvest, growth indices including plant height, numbers of flower, fruit and leaf, fresh weights of fruit, leaf, and stem were recorded. Oven-dry weights of fruit, leaf, and stem were recorded afterwards.

Dry plant samples of leaves were ground to pass a 40-mesh screen for tissue nutrient analysis of N, P, K, Ca, and Mg. A method developed by Hu and Barker (1999) was used to complete the analysis. Nutrient contents of N, P, K, Ca, and Mg accumulated by tomato leaves were used to assess acquisition of nutrients from the media. Tomato growth indices were used for evaluating effects of composts and their combinations on tomato growth and soil fertility.

2.3 Results

2.3.1 Effects of Composts on Tomato Growth

Tables 2.1 and 2.2A-C provide information about how composts and their combinations affected tomato growth. Eleven tomato growth indices were measured, including plant height, numbers of flower, fruit and leaf, fresh weights of fruit, leaf, and stem, dry weights of fruit, leaf, and stem, and total dry weight.

2.3.1.1 Tomato Plant Height

No significant effects on plant height occurred among different components (Table 2.1). The plant heights were an average of 80 cm apiece for the agricultural waste compost and sewage sludge compost media, and an average of 82 cm for yard waste compost medium.

Different regimes (mixes of composts, peat, and/or soil) showed some different effects on plant heights (Table 2.1). The regime of compost alone produced the tallest plant averaging 84 cm. The regime of the combination of compost and soil and peat moss had an average height of 78 cm. Regimes of the combination of compost and soil, and the combination of compost and peat moss had same average height of 80 cm.

Fertilization significantly increased plant height (Table 2.1). Compared to the average height of 85 cm generated by fertilization, non-fertilized treatments only had 77 cm. The relative increase by fertilization was 9.9%.

In each regime, an interaction of different compost media and fertilization was detected (Table 2.2). They are discussed in the following paragraphs.

In the regime of compost alone, fertilization restricted plant height by 8.5% in the agricultural waste compost medium, and by 0.8% in the yard waste compost medium. However, fertilization increased plant height by 8.9% in the sewage sludge compost medium.

In the regime of the combination of compost and soil, fertilization increased plant heights. The increases were by 10.7% in the agricultural waste compost medium, by 8.2% in the sewage sludge compost medium, and by 3.2% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization also increased plant heights. The increases were by 12.3% in the agricultural waste compost medium, by 24.5% in the sewage sludge compost medium, and by 11.5% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased plant heights. The increases were by 16.8% in the agricultural waste compost medium, by 12.5% in the sewage sludge compost medium, and by 27.4% in the yard waste compost medium.

There was a tendency that the treatments with peat moss addition in any compost medium had greater increase in plant height (Table 2.2).

2.3.1.2 Tomato Flower Numbers

There were some differences among the composts regarding the numbers of flower (Table 2.1). Agricultural waste compost medium gave the highest numbers of flower, averaging 45. The sewage sludge and yard waste compost media statistically yielded the same numbers of flower, averaging 37 and 36, respectively.

There were also some differences among the regimes (Table 2.1). The regime of compost alone had the highest numbers of flower, averaging 46. The regimes of the combination of compost and soil, the combination of compost and peat moss, and the combination of compost and soil and peat moss statistically generated the same numbers of flower, averaging 39, 35, and 37 per plant, respectively.

Fertilization significantly increased numbers of flower (Table 2.1). Non-fertilized treatments produced an average of 31 flowers per plant, whereas fertilization generated an average of 48 flowers. The increase by fertilization was by 55.2%.

There were interactions between different compost medium and fertilization on the production of tomato flower (Table 2.2).

In the regime of compost alone, fertilization increased numbers of flower. The increases were by 7.5% in the agricultural waste compost medium, by 0.5% in the sewage sludge compost medium, and by 35.4% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased the numbers of flower. The increases were by 49.3% in the agricultural waste compost medium, by 25.7% in the sewage sludge compost medium, and by 83.2% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased numbers of flower. The increases were by 24.6% in the agricultural waste compost medium, by 350% in the sewage sludge compost medium, and by 73.0% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased numbers of flower. The increases were by 94.5% in the agricultural waste compost medium, by 81.6% in the sewage sludge compost medium, and by 173% in the yard waste compost medium.

There was also a tendency that any treatments with peat moss addition would give a greater increase to numbers of flower (Table 2.2).

2.3.1.3 Tomato Fruit Numbers

There were some differences among the composts (Table 2.1). The yard waste compost medium generated the highest numbers of fruit, averaging 10.9 per plant. The sewage sludge compost medium followed by producing an average of 9.1 fruits. The agricultural waste compost medium produced the least amount of fruit, averaging 7.4.

All regimes statistically produced the same numbers of fruit (Table 2.1), averaging about 9.2 per plant and ranging from 8.0 to 10.0.

Fertilization significantly increased numbers of fruit (Table 2.1). Compared to the average of 5.5 fruits per plant produced by non-fertilized treatments, fertilized treatments produced an average of 12.8 fruits, which was a 133% increase.

There were interactions between different compost medium and fertilization on the production of fruits (Table 2.2).

In the regime of compost alone, fertilization decreased numbers of fruit by 13.7% in the agricultural waste compost medium. However, fertilization increased numbers of fruit by 45.5% in the sewage sludge compost medium and by 69.9% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization tremendously increased numbers of fruit. The increases were by 108% in the agricultural waste compost medium, by 160% in the sewage sludge compost medium, and by 170% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization also greatly increased numbers of fruit. The increases were by 266% in the agricultural waste compost medium, by 150% in the sewage sludge compost medium, and by 106% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization again dramatically increased numbers of fruit. The increases were by 333% in the agricultural waste compost medium, by 167% in the sewage sludge compost medium, and by 338% in the yard waste compost medium.

There was a tendency that the largest increases due to fertilization were in the treatments with peat moss addition (Table 2.2).

2.3.1.4 Tomato Fruit Fresh Weight

There were some differences among the composts (Table 2.1). The yard waste and sewage sludge compost media statistically generated the same fruit fresh weight with averages of 105 and 86 g per plant, respectively. The agricultural waste compost medium produced the least amount of tomato fruit fresh weight, averaging 44 g per plant.

All regimes statistically produced the same fruit fresh weights with average about 77 g per plant, ranging from 67 to 84 g per plant (Table 2.1).

Fertilization significantly increased fruit fresh weights (Table 2.1). Compared to the average of 53 g fresh fruit produced by non-fertilized treatments, fertilization produced an average of 104 g, which was a 97.9% increase.

There was an interaction in each regime between different compost and fertilization on the production of fresh fruits (Table 2.2).

In the regime of compost alone, fertilization suppressed fruit fresh weights by 11.4% in the agricultural waste compost medium. However, fertilization increased fruit fresh weights by 77.9% in the sewage sludge compost medium, and by 85.4% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization tremendously increased fruit fresh weights. The increases were by 90.1% in the agricultural waste compost medium, by 120% in the sewage sludge compost medium, and by 87.1% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization also greatly increased fruit fresh weights. The increases were by 35.9% in the agricultural waste compost medium, by 233% in the sewage sludge compost medium, and by 105% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization also dramatically increased fruit fresh weights. The increases were by 109% in the agricultural waste compost medium, by 108% in the sewage sludge compost medium, and by 117% in the yard waste compost medium.

There was a tendency that the largest increases of fruit fresh weights were in the treatments with peat moss addition (Table 2.2).

2.3.1.5 Tomato Fruit Dry Weight

In general, fruit dry weight followed the trends of fruit fresh weights.

There were differences among the composts (Table 2.1). The yard waste and sewage sludge compost media statistically produced the same fruit dry weights with averages of 6.6 and 5.2 g, respectively. The agricultural waste compost medium produced an average of 3.2 g of fruit dry weight.

All regimes statistically had the same amount of fruit dry weights with an average of 5.0 g per plant, ranging from 4.5 to 5.5 g (Table 2.1).

Fertilization tremendously increased fruit dry weights (Table 2.1). Fertilization produced fruit dry weights with an average of 6.6 g per plant, and non-fertilized treatments had an average of 3.4 g per plant. Fertilization increased average fruit dry weights by 94.1%.

In each regime, there was an interaction between different compost medium and fertilization on the production of fruit dry weights. (Table 2.2).

In the regime of compost alone, fertilization decreased fruit dry weights by 12.5% in the agricultural waste compost medium. However, fertilization increased fruit dry weights by 91.7% in the sewage sludge compost medium, and by 69.8% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization tremendously increased fruit dry weights. The increases were by 94.1% in the agricultural waste compost medium, by 85.0% in the sewage sludge compost medium, and by 89.2% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization also greatly increased fruit dry weights. The increases were by 39.5% in the agricultural waste compost medium, by 225% in the sewage sludge compost medium, and by 109% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization dramatically increased fruit dry weights. The increases were by 115% in the agricultural waste compost medium, by 85.3% in the sewage sludge compost medium, and by 111% in the yard waste compost medium.

There was a tendency that the largest increases were in the treatments with peat moss addition (Tables 2.2).

2.3.1.6 Tomato Leaf Numbers

There were some differences among the composts (Table 2.1). The agricultural waste compost medium produced the highest amount of leaves, averaging 26 per plant.

The sewage sludge and yard waste compost media statistically generated the same numbers of leaf, averaging 23 per plant.

There were some differences among the regimes (Table 2.1). The regime of compost alone produced the highest numbers of leaf, averaging 26 per plant. The other three regimes statistically generated the same numbers of leaf, averaging 23 leaves per plant.

Fertilization dramatically increased numbers of leaf (Table 2.1). Fertilization produced an average of 28 leaves per plant, and non-fertilized treatments had an average of 19 leaves per plant. The increase was 51.1%.

In each regime, different compost medium and fertilization showed interaction on the leaf production (Table 2.2).

In the regime of compost alone, fertilization increased numbers of leaf. The increases were by 2.4% in the agricultural waste compost medium, by 33.3% in the sewage sludge compost medium, and by 44.3% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization also increased numbers of leaves. The increases were by 32.2% in the agricultural waste compost medium, by 42.5% in the sewage sludge compost medium, and by 69.9% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased numbers of leaf. The increases were by 14.4% in the agricultural waste compost medium, by 148% in the sewage sludge compost medium, and by 92.5% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased numbers of leaf. The increases were by 47.5% in the agricultural waste compost medium, by 70.6% in the sewage sludge compost medium, and by 142% in the yard waste compost medium.

There was a tendency that the highest increases of numbers of leaf from fertilization were in the treatments with peat moss addition (Table 2.2). Also the least increase occurred in the agricultural waste compost medium.

2.3.1.7 Tomato Leaf Fresh Weight

All three composts produced significant different leaf fresh weights from each other (Table 2.1). The average leaf fresh weights per plant was 330 g in the agricultural waste compost medium, 259 g in the sewage sludge compost medium, and 221 g in the yard waste compost medium.

There were some differences among the regimes (Table 2.1). The regime of compost alone produced the highest leaf fresh weights, averaging 329 g per plant. All other three regimes statistically produced the same leaf fresh weights, averaging 250 g, ranging from 246 g to 258 g per plant.

Fertilization greatly increased leaf fresh weights (Table 2.1). Fertilization produced leaf fresh weights averaging 388 g per plant, and non-fertilized treatments produced an average of 152 g. Fertilization increased average leaf fresh weights by 155%.

In each regime, different compost medium and fertilization showed an interaction on leaf fresh weights (Table 2.2).

In the regime of compost alone, fertilization increased leaf fresh weights. The increases were by 30.1% in the agricultural waste compost medium, by 103% in the sewage sludge compost medium, and by 112% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased leaf fresh weights. The increases were by 110% in the agricultural waste compost medium, by 157% in the sewage sludge compost medium, and by 242% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased leaf fresh weights. The increases were by 133% in the agricultural waste compost medium, by 562% in the sewage sludge compost medium, and by 255% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased leaf fresh weights. The increases were by 172% in the agricultural waste compost medium, by 285% in the sewage sludge compost medium, and by 456% in the yard waste compost medium.

There was a tendency that the highest increases of leaf fresh weights from fertilization were in the treatments with peat moss addition (Table 2.2). Also the least increase was with the agricultural waste compost medium.

2.3.1.8 Tomato Leaf Dry Weight

Commonly, leaf dry weight followed the same trends of leaf fresh weight.

All three composts produced significantly different leaf dry weights from each other (Table 2.1). The averages were 41.8 g of leaves in the agricultural waste compost medium, 33.0 g in the sewage sludge compost medium, and 29.9 g in the yard waste compost medium.

The leaf dry weights differed among the regimes (Table 2.1). The regime of compost alone produced the highest leaf dry weights, averaging 40.0 g per plant. All other three regimes statistically produced the same leaf dry weights, averaging 33.2 g and ranging from 32.1 to 34.6 g per plant.

Fertilization tremendously increased leaf dry weights (Table 2.1). The fertilization produced leaf dry weights with an averagof 48.5 g, and non-fertilized treatments produced an average of 21.2 g. The increase by fertilization was 129%.

In each regime, different compost medium and fertilization showed an interaction on leaf dry weights (Table 2.2).

In the regime of compost alone, fertilization increased leaf dry weights. The increases were by 20.4% in the agricultural waste compost medium, by 87.2% in the sewage sludge compost medium, and by 79.3% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased average leaf dry weights. The increases were by 61.3% in the agricultural waste compost medium, by 113% in the sewage sludge compost medium, and by 179% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased average leaf dry weights. The increases were by 95.1% in the agricultural waste compost medium, by 614% in the sewage sludge compost medium, and by 318% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased average leaf dry weights. The increases were by 113% in the agricultural waste compost medium, by 253% in the sewage sludge compost medium, and by 500% in the yard waste compost medium.

There was a tendency that the highest increases of dry weights of leaves from fertilization were in the treatments with peat moss addition (Table 2.2). Also the least increase was with the agricultural waste compost medium.

2.3.1.9 Tomato Stem Fresh Weight

There were significant differences among the three composts (Table 2.1). The highest average stem fresh weights of 136 g was produced by the agricultural waste compost medium, followed by 125 g by the sewage sludge compost medium, and then 114 g by the yard waste compost medium.

There were some differences among the regimes (Table 2.1). The regime of compost alone generated the highest stem fresh weights, averaging 143 g. All other regimes statistically produced the same stem fresh weights, averaging about 119 g per plant and ranging from 117 g to 121 g.

Fertilization significantly increased stem fresh weights (Table 2.1). Fertilization produced an average of 162 g of stem fresh weights, and non-fertilized treatments produced an average of 89 g. The increase by fertilization was 82.4%.

In each regime, different compost medium and fertilization showed an interaction on stem fresh weights (Table 2.2).

In the regime of compost alone, fertilization increased stem fresh weights. The increases were by 4.2% in the agricultural waste compost medium, by 46.8% in the sewage sludge compost medium, and by 46.0% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased average stem fresh weights. The increases were by 62.9% in the agricultural waste compost medium, by 62.3% in the sewage sludge compost medium, and by 112% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased average stem fresh weights. The increases were by 79.2% in the agricultural waste compost medium, by 226% in the sewage sludge compost medium, and by 111% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased average stem fresh weights. The increases were by 114% in the agricultural waste compost medium, by 113% in the sewage sludge compost medium, and by 233% in the yard waste compost medium.

There was a tendency that the highest increases of stem fresh weights were in the treatments with peat moss addition (Table 2.2). Also the least increase was with the agricultural waste compost medium.

2.3.1.10 Tomato Stem Dry Weight

Commonly, stem dry weight followed the same trends of stem fresh weight.

There were differences among the composts (Table 2.1). Agricultural waste compost medium produced the highest amount of stem dry weights, averaging 17.9 g per plant. Other two compost media statistically produced the same amount of stem dry weights, averaging 16 g.

There were differences among the regimes (Table 2.1). The regime of compost alone generated the highest stem dry weights, averaging 17.7 g. The regimes of the combination of compost and soil, and the combination of compost and peat moss statistically produced the same amount of stem dry weight, averaging 16.4 g. The regime of the combination of compost and soil and peat moss produced the least amount of stem dry weight, averaging 16.0 g.

Fertilization significantly increased stem dry weights (Table 2.1). Fertilization produced an average of 19.8 g of stem dry weights, and non-fertilized treatments produced an average of 13.3 g. Fertilization increased stem dry weights by 48.9%.

In each regime, different compost medium and fertilization showed an interaction on stem dry weights (Table 2.2).

In the regime of compost alone, fertilization increased average stem dry weights. The increases were by 14.7% in the agricultural waste compost medium, by 21.7% in the sewage sludge compost medium, and by 16.2% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased stem dry weights. The increases were by 8.7% in the agricultural waste compost medium, by 22.3% in the sewage sludge compost medium, and by 64.3% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased stem dry weights. The increases were by 40.0% in the agricultural waste compost medium, by 216% in the sewage sludge compost medium, and by 98.1% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased stem dry weights. The increases were by 52.8% in the agricultural waste compost medium, by 80.5% in the sewage sludge compost medium, and by 204% in the yard waste compost medium.

There was a tendency that the highest increases of stem dry weights were in the treatments with peat moss addition (Table 2.2). Also the least increase was with the agricultural waste compost medium.

2.3.1.11 Tomato Total Dry Weight

There were some differences among the composts (Table 2.1). The agricultural waste compost medium produced the highest amount of total dry weight, averaging 62.9 g. The sewage sludge and yard waste compost media statistically produced the same amount of total dry weight, averaging 53.3 g per plant.

There were some differences among the regimes (Table 2.1). The regime of compost alone generated the highest amount of total dry weight, averaging 62.3 g per plant. All other three regimes statistically produced the same amount of total dry weight, averaging 54.5 g and ranging from53.4 g to 55.5 g per plant.

Fertilization significantly affected the total dry weights (Table 2.1). Fertilization produced average total dry weight of 74.9 g per plant, and non-fertilized treatments generated an average of 38.0 g. The increase by fertilization was 97.1%.

In each regime, different compost medium and fertilization showed an interaction on total dry weights (Table 2.2).

In the regime of compost alone, fertilization increased the total dry weights. The increases were by 17.7% in the agricultural waste compost medium, by 65.5% in the sewage sludge compost medium, and by 56.1% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased the total dry weights. The increases were by 44.4% in the agricultural waste compost medium, by 76.9% in the sewage sludge compost medium, and by 126% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased the total dry weights. The increases were by 72.8% in the agricultural waste compost medium, by 379% in the sewage sludge compost medium, and by 194% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased the total dry weights. The increases were by 92.2% in the agricultural waste compost medium, by 165% in the sewage sludge compost medium, and by 300% in the yard waste compost medium.

There was a tendency that the highest increases of total dry weights from fertilization were in the treatments with peat moss addition (Table 2.2). Also the least increase was with the agricultural waste compost medium.

2.3.1.12 Various Growth Index vs. Total Dry Weight

Figures 2-1 to 2-8 show relationship between each of various growth indices and total plant dry weight. Tests showed that there was a significantly highly positive correlation between each of the most of growth indices and total plant dry weight.

Figure 2-1 shows the relationship between plant height and total dry weight. The regression coefficient is 0.63. Figure 2-2 shows the relationship between the numbers of flower and total dry weight. The regression coefficient is 0.77. Figure 2-3 shows the relationship between the numbers of fruit and total dry weight. The regression coefficient is 0.63. Figure 2-4 shows the relationship between the numbers of leaf and total dry weight. The regression coefficient is 0.92. Figure 2-5 shows the relationship between tomato leaf fresh weight and total dry weight. The regression coefficient is 0.92. Figure 2-6 shows the relationship between tomato leaf dry weight and total dry weight. The regression coefficient is 0.98. Figure 2-7 shows the relationship between stem fresh weight and total dry weight. The regression coefficient is 0.96. Figure 2-8 shows the relationship between stem dry weight and total dry weight. The regression coefficient is 0.94. There was no significant correlation between fruit fresh weight, and fruit dry weight and total dry weight. (The tabulated linear regression coefficients, r values, are 0.515 at 0.01 level, 0.396 at 0.05 level when sample size n=24).

There was very high correlation between each of vegetative growth indices and total dry weight except for tomato plant height. The regression coefficients between each of various vegetative growth indices and total dry weight were above 0.92, except for the coefficient between plant height and total dry weight, which was 0.63. Generally speaking, there was much lower or even poor correlation between each of reproductive indices and total dry weight. The coefficients ranged from 0.28 to 0.77.

The results indicated that the vegetative parts of the plant were the major contributors to the total dry weight. Some of those parameters could be used to predict plant production very well, especially the numbers of leaf. Therefore destructive harvests could be avoided.

2.3.2 Effects of Composts on Leaf Nutrient Accumulations

Table 2.3 and Table 2-4 show the total nutrient accumulations by plant leaves. There was a highly significantly positive correlation between each of individual nutrient accumulation and total plant dry weight. Five major nutrient accumulations were measured for plant leaf samples, including N, P, K, Ca, and Mg.

2.3.2.1 Nitrogen

The three compost media showed different abilities to supply N to plants (Table 2.3). The agricultural waste compost medium supplied the highest amount of N to plants, averaging 1133 mg accumulated in each plant. The sewage sludge and yard waste compost media statistically provided the same amount of N to plants, averaging 868 mg.

The four regimes affected plant N accumulation differently (Table 2.3). Plants in the regime of compost alone accumulated the highest amount of N, averaging 1132 mg per plant. The regime of the combination of compost and soil provided the second largest amount of N to plants, averaging 965 mg accumulated in each plant. The regime of the combination of compost and peat moss provided an average of 881 mg N to each plant. The regime of the combination of compost and soil and peat moss provided an average of 846 mg N to each plant.

Fertilization allowed plants to accumulate significantly higher amount of N compared to non-fertilization (Table 2.3). Fertilization provided an average of 1547 mg N to each plant, and non-fertilized treatments provided an average of 366 mg N. The increase was 323%.

In each regime, different compost medium and fertilization showed an interaction on leaf N accumulation (Table 2.4).

In the regime of compost alone, fertilized tomato plants absorbed an average 89% more N than non-fertilized plants in the agricultural waste compost medium, 181% more N in the sewage sludge compost medium, and 189% more N in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilized plants absorbed an average of 323% more N than non-fertilized plants in the agricultural waste compost medium, 397% more N in the sewage sludge compost medium, and 551% more N in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilized plants absorbed an average of 329% more N than non-fertilized plants in the agricultural waste compost medium, 867% more N in the sewage sludge compost medium, and 542% more N in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilized plants absorbed an average of 451% more N than non-fertilized plants in the agricultural waste compost medium, 600% more N in the sewage sludge compost medium, and 881% more N in the yard waste compost medium.

There was a tendency that the most of largest increases of N accumulation by leaves were in the treatments with peat moss addition (Table 2.4). Also the least increase was with the agricultural waste compost medium.

2.3.2.2 Phosphorus

Different compost media had varying abilities to provide P to plants (Table 2.3). The agricultural and yard waste compost media statistically provided the same amount of P to plants, averaging 320 mg per plant. The sewage sludge compost medium provided an average of 282 mg P to each plant.

The four regimes showed different effects on leaf P accumulation (Table 2.3). The regimes of the combination of compost and peat moss, and the compost alone statistically provided the same amount of P to plants, averaging 372 mg accumulated. It was followed by the regime of the combination of compost and soil and peat moss, which provided an average of 289 mg P to each plant. The regime of the combination of compost and soil provided the least amount of P to plants, averaging 197 mg.

Fertilization provided significantly higher amount of P to plants (Table 2.3). Fertilization provided an average of 459 mg P to each plant, and non-fertilized treatments provided an average of 156 mg. The increase was 194% by fertilization.

In each regime, different compost medium and fertilization showed an interaction on leaf P accumulation (Table 2.4).

In the regime of compost alone, fertilization provided an average of 30% more P than the non-fertilized treatment in the agricultural waste compost medium, 127% more P in the sewage sludge compost medium, and 79% more P in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization provided an average of 148% more P than the non-fertilized treatment in the agricultural waste compost medium, 220% more P in the sewage sludge compost medium, and 278% more P in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization provided an average of 167% more P than the non-fertilized treatment in the agricultural waste compost medium, 563% more P in the sewage sludge compost medium, and 301% more P in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization provided an average of 278% more P than the non-fertilized treatment in the agricultural waste compost medium, 356% more P in the sewage sludge compost medium, and 540% more P in the yard waste compost medium.

There was a tendency that the most of largest increases of P accumulation in tomato leaves were in the treatments with peat moss addition (Table 2.4). Also the least increase was with in the agricultural waste compost medium.

2.3.2.3 Potassium

The three compost media showed significantly different abilities to supply K to plants (Table 2.3). The agricultural waste compost medium had an ability to provide the highest amount of K to plants, averaging 1156 mg accumulated in each plant. The sewage sludge compost medium followed by providing an average of 519 mg K to each plant. The yard waste compost medium had the least supplying ability with an average of 127 mg K accumulated in each plant.

The four regimes exhibited different abilities to provide K to plants (Table 2.3). The regime of compost alone supplied the highest amount of K to plants, averaging 1004 mg. The regime of the combination of compost and soil followed by supplying an average of 546 mg K. Then it was followed by the regime of the combination of compost and soil and peat moss by supplying an average of 447 mg K. The regime of the combination of compost and peat moss supplied the least amount of K to plants, averaging 407 mg.

Fertilization made a significant difference in providing K to plants (Table 2.3). Fertilization provided an average of 854 mg K to each plant, and non-fertilized treatments only provided an average 347 mg K. The increase from fertilization was 146%.

In each regime, different compost medium and fertilization showed an interaction on leaf K accumulation (Table 2.4).

In the regime of compost alone, fertilized plants accumulated 47% more K than the non-fertilized plants in the agricultural waste compost medium, 134% more K in the sewage sludge compost medium, and 157% more K in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilized plants accumulated 191% more K than the non-fertilized plants in the agricultural waste compost medium, 218% more K in the sewage sludge compost medium, and 327% more K in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilized plants accumulated 169% more K than the non-fertilized plants in the agricultural waste compost medium, 238% more K in the sewage sludge compost medium, and 87% more K in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilized plants accumulated an average of 369% more K than the non-fertilized plants in the agricultural waste compost medium, 233% more K in the sewage sludge compost medium, and 76% more K in the yard waste compost medium.

The highest increases of K accumulation were in the treatments with peat moss addition in the agricultural waste the sewage sludge compost media. For the yard waste compost medium, the highest amount of K was provided by the treatments without peat moss addition, and the amount of K supplied by the yard waste compost medium was much lower than those supplied by other two compost media.

2.3.2.4 Calcium

Different compost media showed significantly different abilities to provide Ca to plants (Table 2.3). The sewage sludge compost medium provided the highest amount of Ca to plants, averaging 423 mg accumulated in each plant. The agricultural waste compost medium provided an average of 370 mg. The yard waste compost medium provided the least amount of Ca, averaging 324 mg.

The regimes showed some differences regarding leaf Ca accumulation (Table 2.3). The regime of compost alone provided the highest amount of Ca to plants, averaging 459 mg accumulated in each plant. The other three regimes statistically provided the same amount of Ca to plants, averaging 344 mg per plant.

Fertilized plants accumulated significantly more Ca than non-fertilized plants (Table 2.3). The averages were 500 mg and 244 mg Ca respectively. The increase from fertilization was 105%.

In each regime, different compost medium and fertilization showed an interaction on leaf Ca accumulation (Table 2.4).

In the regime of compost alone, fertilization increased leaf Ca accumulation. The increases were by 49% in the agricultural waste compost medium, by 45% in the sewage sludge compost medium, and by 68% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased leaf Ca accumulation. The increases were by 104% in the agricultural waste compost medium, by 105% in the sewage sludge compost medium, and by 146% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization increased leaf Ca accumulation. The increases were by 67% in the agricultural waste compost medium, by 307% in the sewage sludge compost medium, and by 142% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization increased leaf Ca accumulation. The increases were by 116% in the agricultural waste compost medium, by 175% in the sewage sludge compost medium, and by 229% in the yard waste compost medium.

There was a tendency that the most of largest increases of leaf Ca accumulation were in the treatments with peat moss addition (Table 2.4). Also the least increase from fertilization was with the agricultural waste compost medium.

2.3.2.5 Magnesium

There were significant differences among the three compost media in supplying Mg (Table 2.3). The agricultural waste compost medium provided the highest amount of Mg to plants, averaging 131 mg for each plant. The yard waste compost medium followed by providing an average of 100 mg of Mg to each plant. The sewage sludge compost medium supplied the least amount of Mg to plants with an average of 75 mg.

The regimes showed differences in supplying Mg to plants (Table 2.3). The regime of compost alone provided the largest amount of Mg to plants, averaging 132 mg per plant. The regime of the combination of compost and soil provided the second highest amount of Mg to plants, averaging 98 mg per plant. The regime of the combination of compost and peat moss provided the least amount of Mg with an average of 87 mg. The regime of the combination of compost and soil and peat moss provided an average of 91 mg of Mg.

Fertilization made significant differences in increasing leaf Mg accumulation (Table 2.3). Fertilization provided an average of 139 mg of Mg to each plant, non-fertilized treatments provided an average 65 mg. The increase from fertilization was 114%.

In each regime, different compost medium and fertilization showed an interaction on leaf Mg accumulation (Table 2.4).

In the regime of compost alone, fertilization increased leaf Mg accumulation. Fertilized plants accumulated an average of 31% more Mg in each plant in the agricultural waste compost medium, 56% more Mg in the sewage sludge compost medium, and 48% more Mg in the yard waste compost medium than non-fertilized plants.

In the regime of the combination of compost and soil, fertilized plants accumulated more Mg than non-fertilized plants. They accumulated an average of 94% more Mg in the agricultural waste compost medium, 140% more in the sewage sludge compost medium, and 202% more in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilized plants accumulated more Mg than non-fertilized plants. An average of 84% more Mg was accumulated in the agricultural waste compost medium, 350% more in the sewage sludge compost medium, and 175% more in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilized plants accumulated more Mg than non-fertilized plants. An average of 157% more Mg was accumulated in the agricultural waste compost medium, 252% more in the sewage sludge compost medium, and 410% more in the yard waste compost medium.

There was a tendency that the most of largest increases of leaf Mg accumulation were in the treatments with peat moss addition in all compost media (Table 2.4). Also the least increase was with the agricultural waste compost medium.

2.3.2.6 Total Nutrient Accumulations vs. Total Plant Dry Weight

Figures 2-9 to 2-13 present the relationship between each of single leaf nutrient accumulation and the total plant dry weight. All correlations were in the form of natural logarithme.

A very high regression coefficient of 0.96 was between total leaf N accumulation and total plant dry weight. The relationship between the total leaf P accumulations and the total plant dry weight was expressed by the regression coefficient of 0.86. The relationship between the total leaf K accumulation and the total plant dry weight was described by the regression coefficient of 0.44. The relationship between the total leaf Ca accumulation and the total plant dry weight was determined by the regression coefficient of 0.82. The relationship between the total leaf Mg accumulation and the total plant dry weight was determined by the regression coefficient of 0.82 (The tabulated regression coefficients, r values, are 0.515 at 0.01 level, 0.396 at 0.05 level when sample size n=24).

2.3.3 Effects of Composts on Soil Nutrient Residual Availability

Tables 2.5 and 2.6 present the entire picture of soil Residual available nutrients, which was the amount of soil nutrients remaining in the media at the end of the experiment, affected by different compost media. Five major soil nutrient elements were measured, including N, P, K, Ca, and Mg.

2.3.3.1 Nitrogen

There were no significant differences among the compost media regarding to soil N residual availability (Table 2.5), averaging 60 mg/kg for each.

The regimes made some differences in N residual availability (Table 2.5). The regime of the combination of compost and peat moss had the highest amount of residual available N with an average of 75 mg/kg. The regimes of compost alone and the combination of compost and soil and peat moss statistically had the same amount of residual available N with an average of 59 mg/kg. The regime of the combination of compost and soil had the least amount of residual available N with an average of 50 mg/kg.

Fertilization significantly decreased the residual available N in the media (Table 2.5). The non-fertilized treatments had an average of 67 mg/kg residual available N, and fertilized treatments had an average of 54 mg/kg residual available N. The decrease from fertilization was 20.5%, perhaps due to the increased growth stimulated by fertilization.

The decreasing effects were detected in most regimes. However, there were some increases of soil residual nutrients in the regimes without peat moss addition in the sewage sludge compost medium (Table 2.6).

In the regime of compost alone, fertilization decreased residual available N by 19.3% in the agricultural waste compost medium and by 44.7% in the yard waste compost medium. However it increased residual available N by 173% in the sewage sludge compost medium.

In the regime of the combination of compost and soil, fertilization decreased residual available N by 32.8% in the agricultural waste compost medium and by 0.7% in the yard waste compost medium. However fertilization increased the residual available N by 105% in the sewage sludge compost medium.

In the regime of the combination of compost and peat moss, fertilization reduced residual available N. The decreases were by 46.1% in the agricultural waste compost medium, by 43.5% in the sewage sludge compost medium, and by 18.3% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization reduced soil residual available N. The decreases were by 20.5% in the agricultural waste compost medium, by 62.3% in the sewage sludge compost medium, and by 38.7% in the yard waste compost medium.

Fertilization increased residual available N only in the regimes of compost alone and the combination of compost and soil in the sewage sludge compost medium (Table 2.6). In other regimes, it reduced soil residual available N. Perhaps this was the result in response to increased plant growth and enhanced removal of N.

2.3.3.2 Phosphorus

There were significant differences among the three compost media regarding to soil P residual availability (Table 2.5). The agricultural waste compost medium had the highest amount of residual available P with an average of 44 mg/kg. It followed by the yard waste compost medium with an average of 31 mg/kg. The sewage sludge compost medium had the least amount of residual available P with an average of 23 mg/kg.

All regimes showed significant differences in soil P residual availability (Table 2.5). The regime of the combination of compost and peat moss had the highest amount of residual available P with an average of 55 mg/kg. It followed by the regime of compost alone with an average of 45 mg/kg, then by the regime of the combination of compost and soil and peat moss with an average of 18 mg/kg, finally by the regime of combination of compost and soil with an average of 12 mg/kg.

Fertilization significantly increased soil P residual availability (Table 2.5). The fertilized treatments increased soil residual available P from 31 mg/kg in the non-fertilized treatments to 34 mg/kg. The increase from fertilization was 9.7%.

There were variations in residual P availability in different regimes (Table 2.6).

In the regime of compost alone, fertilization decreased soil residual available P by 7.9% in the agricultural waste compost medium and by 7.1% in the yard waste compost medium. However, it increased soil residual available P by 20.9% in the sewage sludge compost medium.

In the regime of the combination of compost and soil, fertilization increased soil residual available P. The increases were by 24.2% in the agricultural waste compost medium, by 19.1% in the sewage sludge compost medium, and by 22.2% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization decreased soil residual available P by 25.1% in the agricultural waste compost medium. However, there were 35.5% increase in the sewage sludge compost medium and 76% increase in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization decreased soil residual available P by 32.4% in the agricultural waste compost medium. However, there were a 19.2% increase in the sewage sludge compost medium and 13.4% increase in the yard waste compost medium.

It was noted that most decreases in soil residual available P were in the agricultural waste compost medium, and the sewage sludge compost medium showed all increases. Also very low amount of soil residual available P was in the regimes with soil addition in the sewage sludge and yard waste compost media (Table 2.6). Perhaps soil fixed some P.

2.3.3.3 Potassium

There were significant differences among the three compost media (Table 2.5). The agricultural waste compost medium had the highest amount of soil residual available K, with an average of 434 mg/kg. The sewage sludge compost medium had the second highest amount of soil residual available K with an average of 206 mg/kg. The yard waste compost medium had the least amount of soil residual available K with an average of 99 mg/kg.

There were also significant differences among different regimes (Table 2.5). The regime of compost alone had the highest amount of soil residual available K, with an average of 384 mg/kg. The regime of the combination of compost and peat moss had the second highest amount of soil residual available K with an average of 309 mg/kg. They were followed by the regime of the combination of compost and soil and peat moss with an average of 173 mg/kg. The regime of the combination of compost and soil had the least amount of soil residual available K with an average of 119 mg/kg.

Fertilization made a significant difference in increasing soil residual available K (Table 2.5). Fertilized treatments had an average of 266 mg/kg residual available K, and non-fertilized treatments had an average of 226 mg/kg. It was an increase by 17.7% due to the fertilization.

As with phosphorus, there were some variations in different regimes (Table 2.6).

In the regime of compost alone, fertilization decreased soil residual available K by 18.2% in the agricultural waste compost medium. However, it increased soil residual available K by 17.2% in the sewage sludge compost medium and by 45.4% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased soil residual available K. The increases were by 36.3% in the agricultural waste compost medium, by 76.8% in the sewage sludge compost medium, and by 84.1% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization decreased soil residual available K by 13.6% in the agricultural waste compost medium. However, it increased the soil residual available K by 323% in the sewage sludge compost medium and by 114% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization decreased the soil residual available K by 36.7% in the agricultural waste compost medium. However, it increased the soil residual available K by 13.6% in the sewage sludge compost medium and by 22.6% in the yard waste compost medium.

All decreases with fertilization were in the agricultural waste compost medium, and lower K residual availability was in the regimes with soil addition. However, the agricultural waste compost medium had the highest amount of residual available K (Table 2.6).

2.3.3.4 Calcium

There were differences among the three compost media (Table 2.5). The sewage sludge compost medium had the highest amount of residual available Ca with an average of 226 mg/kg. The agricultural waste compost medium had the second highest amount of residual available Ca with an average of 219 mg/kg. The yard waste compost medium had the least amount of residual available Ca with an average of 206 mg/kg.

There were differences among the regimes (Table 2.5). The regimes of the combination of compost and peat moss, and compost alone statistically had the same amount of residual available Ca, averaging 264 mg/kg. The regime of the combination of compost, soil and peat moss had an average of 215 mg/kg rsidual available Ca. The regime of the combination of compost and soil had the least amount of soil residual available Ca with an average of 125 mg/kg.

Fertilization made a significant difference in soil Ca residual availability (Table 2.5). Fertilized treatments had an average of 197 mg/kg residual available Ca, and non-fertilized treatments had an average of 237 mg/kg. The decrease by fertilization was 20.3%.

The decrease effects were everywhere in all regimes of all kinds of compost media (Table 2.6).

In the regime of compost alone, fertilization decreased residual available Ca. The decreases were by 20.5% in the agricultural waste compost medium, by 9.6% in the sewage sludge compost medium, and by 13.6% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization decreased residual available Ca. The decreases were by 1.7% in the agricultural waste compost medium, by 11.9% in the sewage sludge compost medium, and by 20.6% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization decreased residual available Ca. The decreases were by 14.6% in the agricultural waste compost medium, by 15.7% in the sewage sludge compost medium, and by 21.6% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization decreased residual available Ca. The decreases were by 33.1% in the agricultural waste compost medium, by 14.5% in the sewage sludge compost medium, and by 15.9% in the yard waste compost medium.

Fertilization reduced residual available Ca. The largest decrease in soil Ca residual availability was in the regime of the combination of compost and soil and peat moss in the agricultural waste compost medium (Table 2.6).

2.3.3.5 Magnesium

There were significant differences among the three compost media (Table 2.5). The yard waste compost medium had the highest amount of residual available Mg with an average of 25 mg/kg. The agricultural waste compost medium had the second highest amount of residual available Mg with an average of 21 mg/kg Mg. The sewage sludge compost medium had the least amount of residual available Mg with an average of 13 mg/kg.

There were differences among the four regimes (Table 2.5). The regimes of compost alone and the combination of compost and peat moss statistically had the same amount of residual available Mg with an average of 26 mg/kg. The regime of the combination of compost and soil and peat moss had an average of 20 mg/kg residual available Mg. The regime of the combination of compost and soil had the least amount of soil residual available Mg with an average of 8 mg/kg.

There was a significant difference between fertilized and non-fertilized treatments (Table 2.5). The fertilized treatments had an average of 17 mg/kg residual available Mg, and non-fertilized treatments had an average of 23 mg/kg residual available Mg. The decrease by fertilization was 24.8%.

The decreases were dominant with exception of one increase in residual available Mg by fertilization (Table 2.6).

In the regime of compost alone, fertilization decreased Mg residual availability. The decreases were by 17.3% in the agricultural waste compost medium, by 1.1% in the sewage sludge compost medium, and by 22.5% in the yard waste compost medium.

In the regime of the combination of compost and soil, fertilization increased Mg residual availability by 5.4% in the agricultural waste compost medium. However, it decreased Mg residual availability by 21.1% in the sewage sludge compost medium and by 47.7% in the yard waste compost medium.

In the regime of the combination of compost and peat moss, fertilization decreased Mg residual availability. The decreases were by 29.7% in the agricultural waste compost medium, by 19.7% in the sewage sludge compost medium, and by 27.4% in the yard waste compost medium.

In the regime of the combination of compost and soil and peat moss, fertilization decreased Mg residual availability. The decreases were by 39.9% in the agricultural waste compost medium, by 23.6 % in the sewage sludge compost medium, and by 28.3% in the yard waste compost medium.

Peat moss addition significantly increased Mg residual availability in the sewage sludge compost medium.

2.4 Discussion

2.4.1 Effects of Composts on Plant Growth

Results show that each of the three compost media affected tomato growth differently. Generally speaking, the agricultural waste compost medium gave the best results, especially for the vegetative production of the plants. For the reproductive production of the plants, commonly the sewage sludge and yard waste compost media gave the better results. However duration of reproductive production of plants was limited due to the experimental considerations. The yard waste compost medium was deemed the worst overall. The different results were attributed to the nutrient differences existing among the composts used. The higher the nutrient contents, the better the results.

The regimes affected growth differently. Compost alone produced the best results in nearly every aspect. However, there were no significant differences among the four regimes for the fruit production of the plants.

For maximum production of crop plants, fertilization is necessary. When taking fertilization into account, the regimes with peat moss addition seemed the most responsible with enhanced growth. The increases by the fertilization were much greater in these regimes even though the fertilization basically increased all growth indices in all regimes. It was common that the increases imparted by fertilization in the agricultural waste compost medium were limited due to their higher content of plant nutrients.

There were highly correlated relationships between each of most growth indices and total plant dry weight. Numbers of flower and numbers of leaf could be used to predict the tomato plant production without undertaking destructive harvests, especially for the experiment purposes in the controlled environments.

2.4.2 Effects of Composts on Leaf Nutrient Accumulations

There were significantly highly correlated relationships between each of the five major nutrient accumulations by tomato leaves and total plant dry weight. The analysis of leaf nutrient accumulations further showed that the agricultural waste compost medium was the best for tomato growth. And again, when taking fertilization into account, the regimes with peat moss addition to compost were most responsible in nutrient accumulations. The increases by the fertilization were much greater in these regimes even though the fertilization basically increased nutrient accumulations in all regimes. It was common that the increases in accumulations by fertilization in the agricultural waste compost medium were limited due to their higher content of plant nutrients.

2.4.3 Effects of Composts on Soil Nutrient Residual Availability

The three compost media affected the soil nutrients remaining in the media after harvest differently. The agricultural waste compost medium again seemed the best overall. They had more residual available P and K than other two compost media and statistically had the same amount of residual available N as the others. The sewage sludge compost medium seemed the worst regarding residual available P and Mg in soil medium. The yard waste compost medium was the worst in K residual availability. The regimes of the combination of compost and peat moss, and compost alone were overall better combinations to have more residual available nutrients in the soil medium. Any regimes with soil addition caused much less residual available nutrients in the soil medium except N. Fertilization greatly increased plant accumulations of N and Mg and reduced soil availability of those nutrients. The residual nutrient is an indicator of the medium to support a second crop without further fertilization

Table 2.1 Growth Index Comparison for 1st Experiment

Index	Variables								
	Composts			Regimes				Fertilization	
	AW	SS	YW	C	CS	CP	CPS	Yes	No
Height (cm)	80a	80a	82a	84a	80ab	81ab	78b	85a	77b
No. of Flower	44a	37b	36b	46a	39b	35b	37b	48a	31b
No. of Fruit	7.4b	9.1ab	10.9a	10.0a	8.0a	9.2a	9.4a	12.8a	5.5b
Fruit FW (g)	44b	86a	105a	79a	67a	84a	84a	104a	53b
Fruit DW (g)	3.2b	5.2a	6.6a	4.7a	4.5a	5.5a	5.3a	6.6a	3.4b
No. of Leaf	26a	23b	23b	26a	23b	22b	23b	28a	19b
Leaf FW (g)	330a	259b	221c	329a	258b	246b	247b	388a	152b
Leaf DW (g)	42a	33b	30c	40a	35b	33b	32b	49a	21b
Stem FW (g)	136a	125b	114c	143a	120b	121b	117b	162a	89b
Stem DW (g)	18a	16b	16b	18a	16ab	16ab	16b	20a	13b
Total DW (g)	63a	54b	52b	62a	55b	55b	53b	75a	38b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).
See Table 2.2 for abbreviations.

Table 2.2 1st Experiment Growth Index Averages for A: Agricultural Waste Compost, B: Sewage Sludge Compost, and C: Yard Waste Compost

Regime	Fertilization	Index										
		Height	Flower #	Fruit			Leaf			Stem		
			#	#	FW	DW	#	FW	DW	FW	DW	TDW
		cm			--------g-------			------------------------------g--------------------------				
A: Agricultural Waste Compost												
C	Yes	78	57	6.3	20	1.4	30	456	51	160	20	72
	No	85	53	7.3	22	1.6	29	351	42	154	17	61
CS	Yes	85	52	8.3	41	3.3	28	403	48	159	18	69
	No	77	35	4.0	21	1.7	21	192	30	98	16	48
CP	Yes	87	41	12.8	74	5.3	26	444	56	169	22	83
	No	78	33	3.5	54	3.8	23	190	29	94	16	48
CPS	Yes	83	57	14.3	82	5.8	30	441	54	174	22	82
	No	71	29	3.3	39	2.7	20	162	25	81	14	42

Abbreviations: C= Compost Alone; CS= Compost and Soil; CP= Compost and Peat Moss; CPS= Compost and Peat Moss and Soil; FW=Fresh Weight; DW= Dry Weight and TDW=Total Dry Weight.

Continued next page

Regime	Fertilization	Height	Flower #	Fruit			Leaf			Stem		TDW
			#	#	FW	DW	#	FW	DW	FW	DW	
		cm			--------g-------			------------------------------g--------------------------				
B: Sewage Sludge Compost												
C	Yes	86	39	12.8	129	6.9	28	434	51	170	19	77
	No	79	38	8.8	73	3.6	21	214	27	116	16	47
CS	Yes	82	48	12.5	119	7.4	28	378	48	156	19	75
	No	75	38	4.8	54	4.0	19	147	22.7	96	16	42
CP	Yes	87	50	12.0	121	7.8	27	374	47	174	22	77
	No	70	14	4.8	36	2.4	11	57	7	53	7	16
CPS	Yes	86	46	12.8	104	6.3	29	371	47	162	20	74
	No	76	26	4.8	50	3.4	17	97	13	76	11	28

Abbreviations: C= Compost Alone; CS= Compost and Soil; CP= Compost and Peat Moss; CPS= Compost and Peat Moss and Soil; FW=Fresh Weight; DW= Dry Weigh and TDW=Total Dry Weight.

Continued next page

		Index										
Regime	Fertilization	Height	Flower #	Fruit			Leaf			Stem		
			#	#	FW	DW	#	FW	DW	FW	DW	TDW
		cm			--------g-------			-----------------	-------------	g-----------	---------------	------------
C: Yard Waste Compost												
C	Yes	87	51	15.8	150	9.0	30	353	44	153	19	72
	No	88	37	9.3	81	5.3	21	166	25	105	16	46
CS	Yes	81	40	13.5	109	7.0	26	330	44	143	18	69
	No	79	22	5.0	58	3.7	15	97	16	68	11	31
CP	Yes	87	46	15.0	147	9.4	31	322	48	159	21	78
	No	78	26	7.3	72	4.5	16	91	11	75	11	27
CPS	Yes	86	46	17.5	155	9.3	30	347	45	162	21	76
	No	68	17	4.0	71	4.4	12	62	8	49	7	19

Abbreviations: C= Compost Alone; CS= Compost and Soil; CP= Compost and Peat Moss; CPS= Compost and Peat Moss and Soil; FW=Fresh Weight; DW= Dry Weight and TDW=Total Dry Weight.

Table 2.3 Tomato Leaf Nutrient Accumulations for 1st Experiment

Element	Variables								
	Composts			Regimes				Fertilization	
(mg)	AW	SS	YW	C	CS	CP	CPS	Yes	No
N	1133a	902b	834b	1132a	965b	881bc	846c	1547a	366b
P	326a	282b	314a	362a	197c	382a	289b	459a	156b
K	1156a	519b	127c	1004a	546b	407c	447bc	854a	347b
Ca	370b	423a	324c	459a	367b	328b	336b	500a	244b
Mg	131a	76c	100b	132a	98b	87c	91bc	139a	65b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; YW= Yard Waste Compost; C= Compost Alone; CS= Compost and Soil; CP= Compost and Peat Moss; and CPS= Compost and Peat Moss and Soil.

Table 2.4 1st Experiment Leaf Nutrient Concentration (%)

Compost	Regime	Fertilization	N	P	K	Ca	Mg
AW	C	Yes	3.75	0.76	4.32	0.76	0.39
		No	2.38	0.70	3.53	0.62	0.36
	CS	Yes	3.62	0.63	2.57	1.04	0.32
		No	1.41	0.41	1.46	0.83	0.27
	CP	Yes	3.00	1.15	2.50	0.89	0.29
		No	1.36	0.84	1.81	1.04	0.31
	CPS	Yes	3.07	0.91	3.05	0.99	0.29
		No	1.18	0.51	1.39	0.98	0.24
SS	C	Yes	3.00	0.96	2.67	1.46	0.21
		No	1.95	0.81	2.05	1.92	0.24
	CS	Yes	3.45	0.59	2.04	1.16	0.25
		No	1.47	0.39	1.37	1.20	0.22
	CP	Yes	2.85	1.18	0.65	0.99	0.19
		No	2.15	1.25	1.38	1.70	0.31
	CPS	Yes	3.12	0.97	0.87	1.10	0.24
		No	1.61	0.76	0.93	1.44	0.25
YW	C	Yes	3.06	1.16	0.64	1.20	0.36
		No	1.90	1.16	0.44	1.29	0.43
	CS	Yes	3.30	0.69	0.60	1.03	0.33
		No	1.42	0.51	0.38	1.17	0.30
	CP	Yes	3.22	1.31	0.21	0.89	0.26
		No	2.09	1.36	0.46	1.53	0.39
	CPS	Yes	2.93	1.07	0.23	0.89	0.33
		No	1.80	1.01	0.82	1.65	0.40

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; YW= Yard Waste Compost; C= Compost Alone; CS= Compost/Soil; CP= Compost/Peat Moss; and CPS= Compost/Peat Moss/Soil.

Table 2.5 1st Experiment Leaf Nutrient Accumulations (mg)

Compost	Regime	Fertilization	N	P	K	Ca	Mg	TDW
AW	C	Yes	1903	387	2196	387	199	72
		No	1005	297	1492	259	152	61
	CS	Yes	1735	302	1235	497	151	69
		No	410	122	425	244	78	46
	CP	Yes	1668	640	1391	495	160	83
		No	389	240	517	297	87	48
	CPS	Yes	1652	491	1643	535	159	82
		No	300	130	350	248	62	42
SS	C	Yes	1527	481	1363	747	106	77
		No	543	212	583	516	68	47
	CS	Yes	1659	285	989	558	120	75
		No	334	89	311	272	50	42
	CP	Yes	1325	550	294	464	90	77
		No	137	83	87	114	20	16
	CPS	Yes	1476	456	406	522	116	74
		No	211	100	122	190	33	28
YW	C	Yes	1349	511	280	530	158	72
		No	467	286	109	316	107	46
	CS	Yes	1432	302	256	447	142	69
		No	220	80	60	182	47	31
	CP	Yes	1527	621	99	423	121	78
		No	238	155	53	175	44	27
	CPS	Yes	1305	480	102	401	148	76
		No	133	75	58	122	29	19

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; YW= Yard Waste Compost; C= Compost Alone; CS= Compost & Soil; CP= Compost and Peat Moss; CPS= Compost and Peat Moss and Soil; and TDW=Total Dry Weight.

Table 2.6 Comparison of Soil Residual Available Nutrient Contents for 1st Experiment

Element	Composts			Regimes				Fertilization	
(mg/kg)	AW	SS	YW	C	CS	CP	CPS	Yes	No
N	57.7 a	58.0 a	65.9 a	59.0 ab	49.7 b	75.2 a	58.2 ab	53.6 b	67.5 a
P	43.6 a	23.3 c	30.8 b	44.9 b	12.0 d	55.5 a	17.8 c	33.8 a	31.3 b
K	434 a	206 b	99 c	384 a	119 d	309 b	173 c	266 a	226 b
Ca	219 ab	226 a	206 b	262 a	125 c	266 a	215 b	197 b	237 a
Mg	21.4 b	13.3 c	25.1 a	27.0 a	8.3 c	25.0 a	19.5 b	17.1 b	22.8 a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; YW= Yard Waste Compost; C= Compost Alone; CS= Compost and Soil; CP= Compost and Peat Moss; and CPS= Compost and Peat Moss and Soil.

Table 2-7 1st Experiment Soil Available Nutrient Content (mg/kg)

Compost	Regime	Fertilization	N	P	K	Ca	Mg
AW	C	Yes	43	52	618	182	21
		No	53	56	756	229	26
	CS	Yes	46	29	280	157	12
		No	68	240	205	159	11
	CP	Yes	47	50	426	234	22
		No	87	66	494	274	31
	CPS	Yes	53	29	269	209	19
		No	66	43	425	313	31
SS	C	Yes	83	44	246	245	9
		No	30	36	210	271	9
	CS	Yes	60	5	85	106	5
		No	29	4	48	121	6
	CP	Yes	55	46	668	286	22
		No	97	34	158	339	27
	CPS	Yes	37	9	124	205	13
		No	98	8	109	239	17
YW	C	Yes	52	39	281	300	43
		No	94	42	193	347	55
	CS	Yes	47	6	61	92	6
		No	47	5	33	116	11
	CP	Yes	86	88	76	204	20
		No	105	50	35	261	28
	CPS	Yes	36	9	62	149	16
		No	59	8	51	177	23

Abbreviations: AW=Agricultural Waste Compost; SS= Sewage Sludge Compost; YW= Yard Waste Compost; C= Compost Alone; CS= Compost & Soil; CP= Compost and Peat Moss; and CPS= Compost & Peat Moss & Soil.

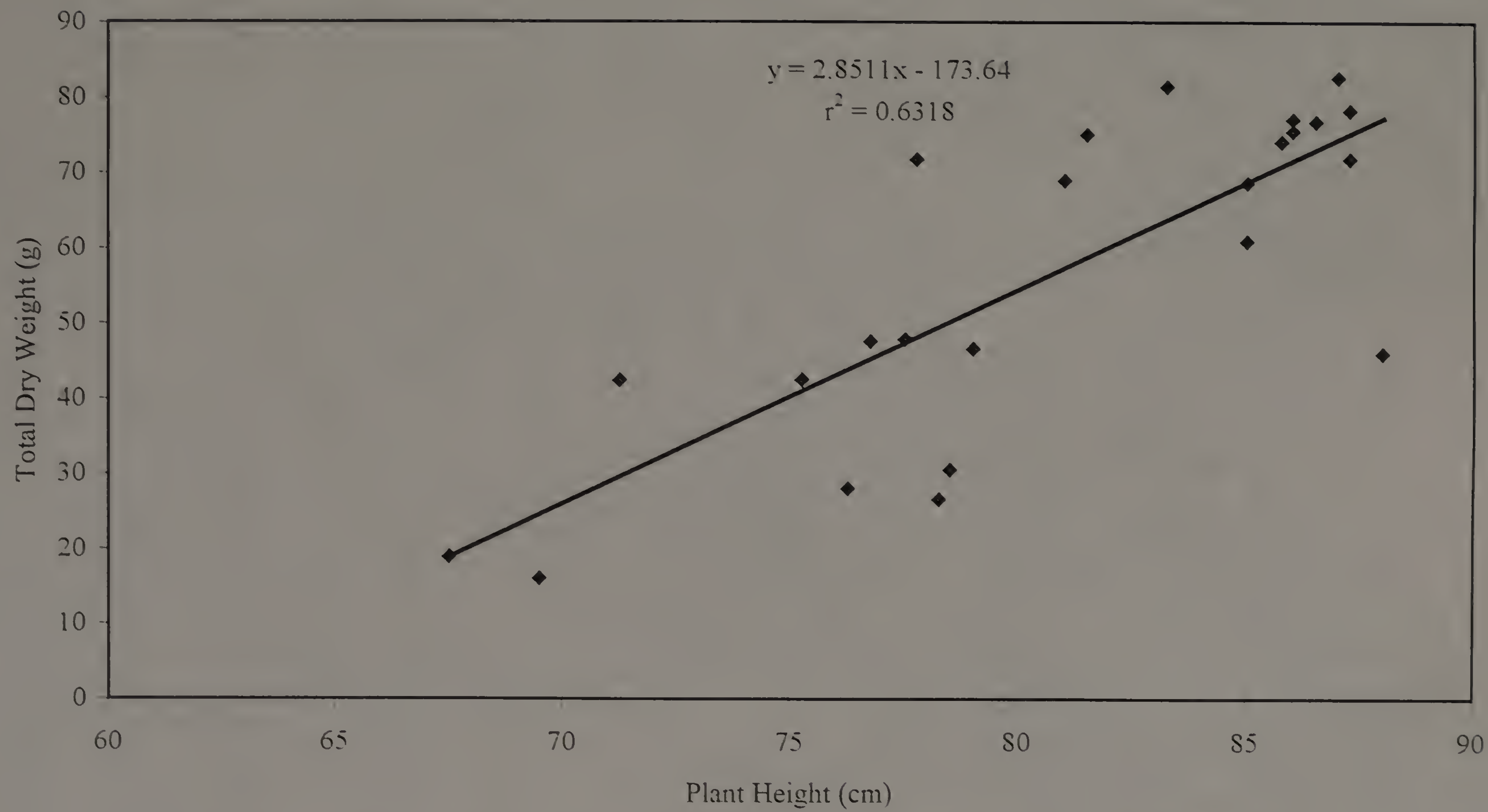


Figure 2.1 Relationship between Plant Height and Total Dry Weight for 1st Experiment

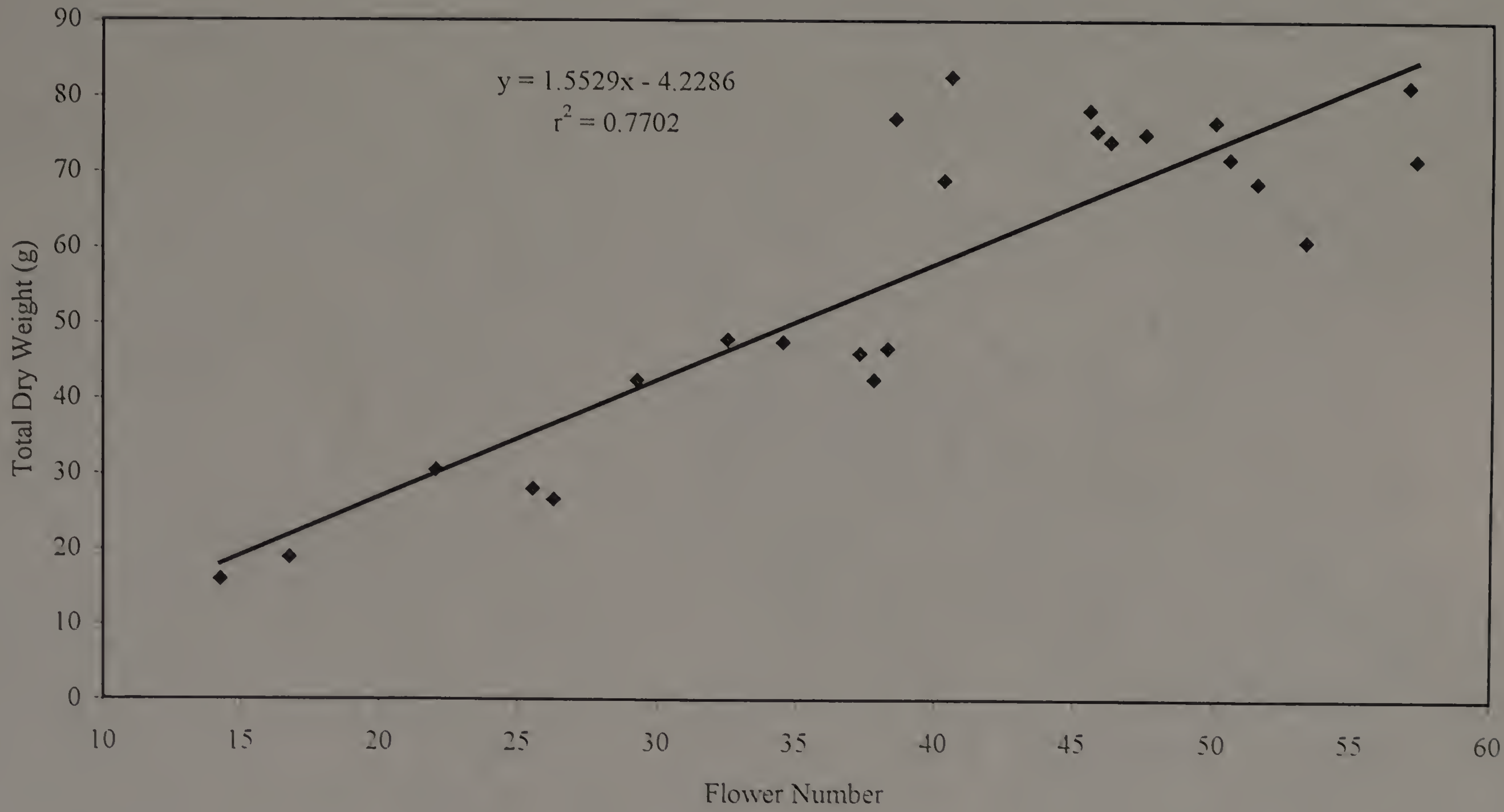


Figure 2.2 Relationship between Flower # and Total Dry Weight for 1st Experiment

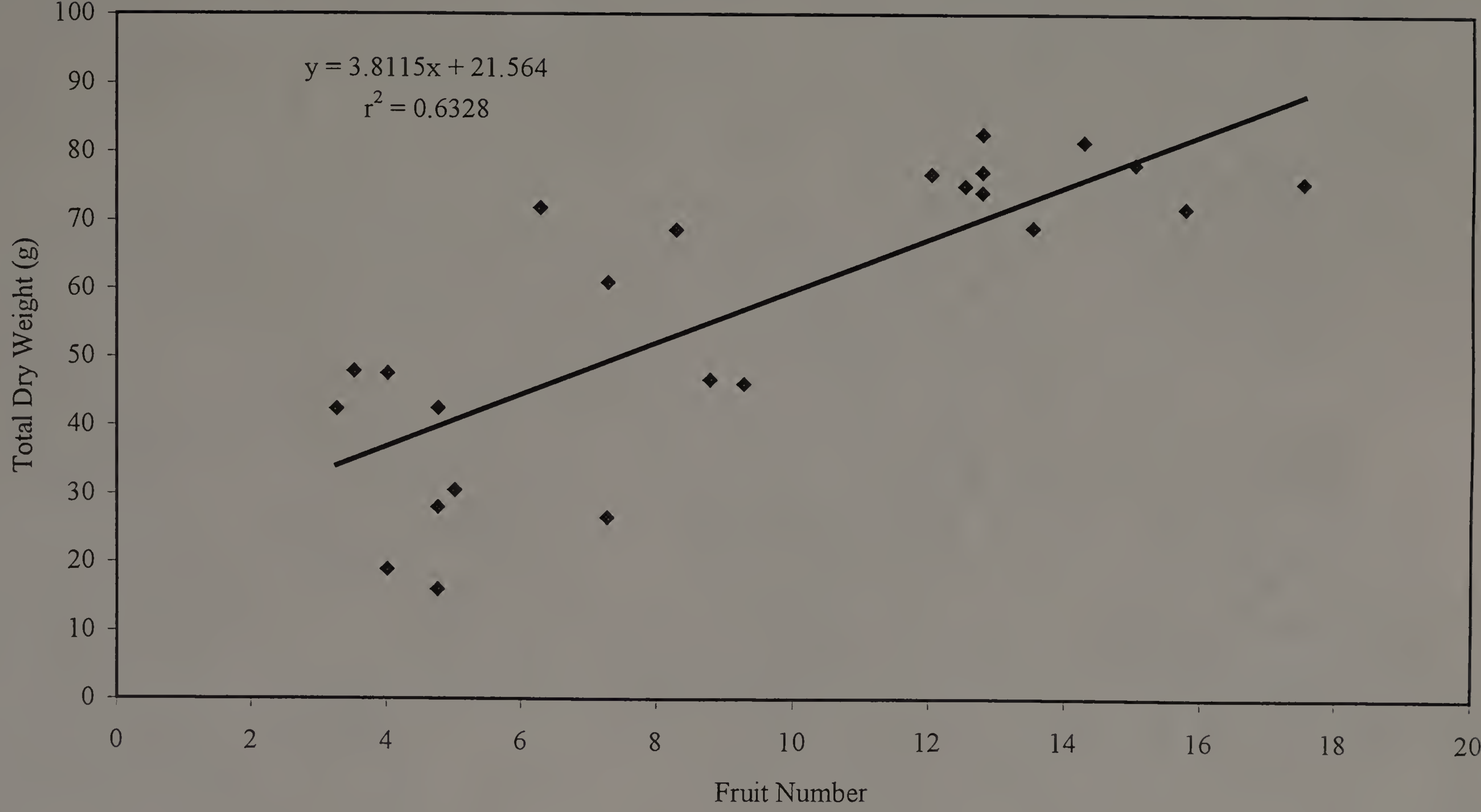


Figure 2.3 Relationship between Fruit # and Total Dry Weight for 1st Experiment

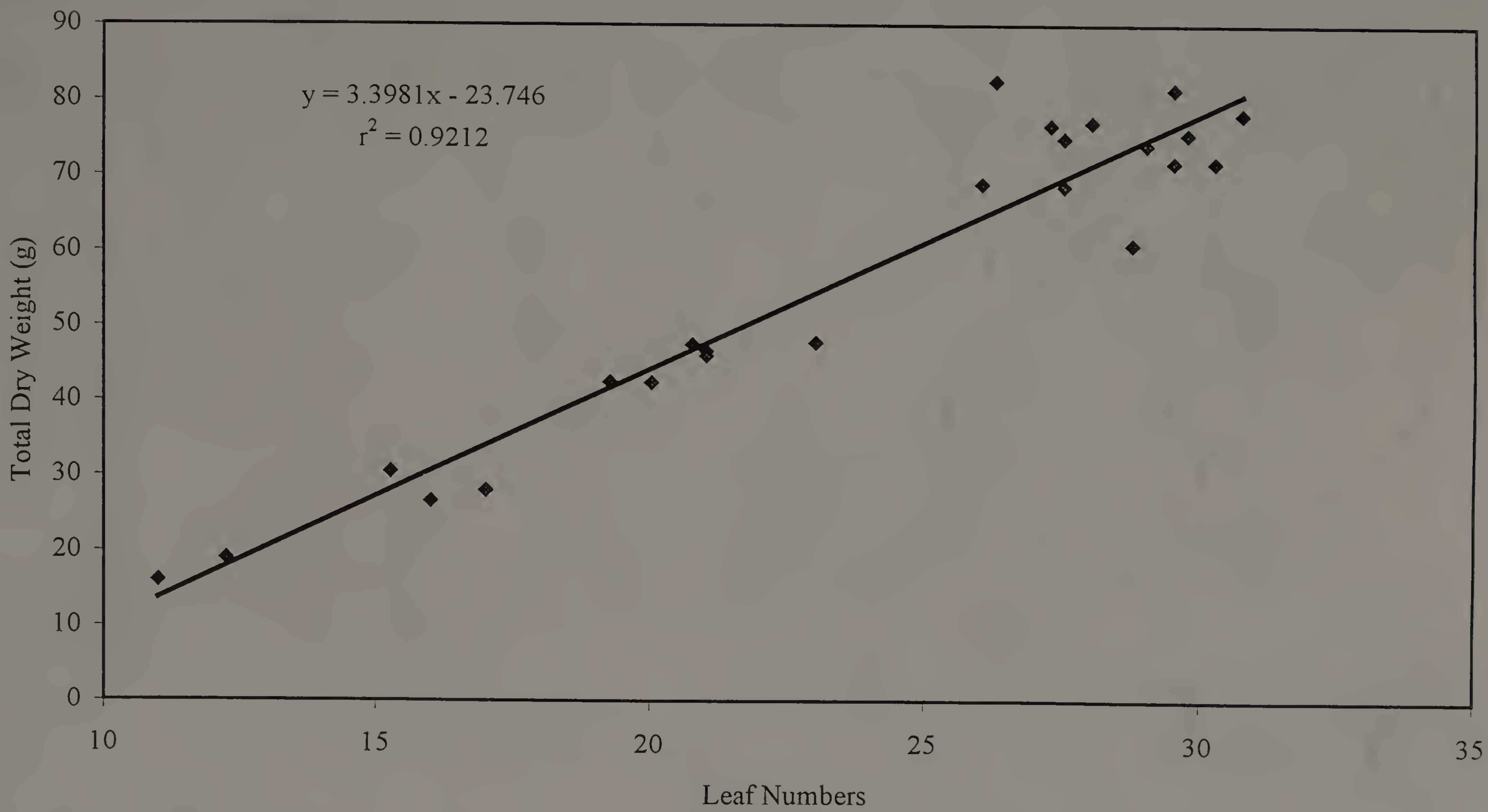


Figure 2.4 Relationship between Leaf # and Total Dry Weight for 1st Experiment

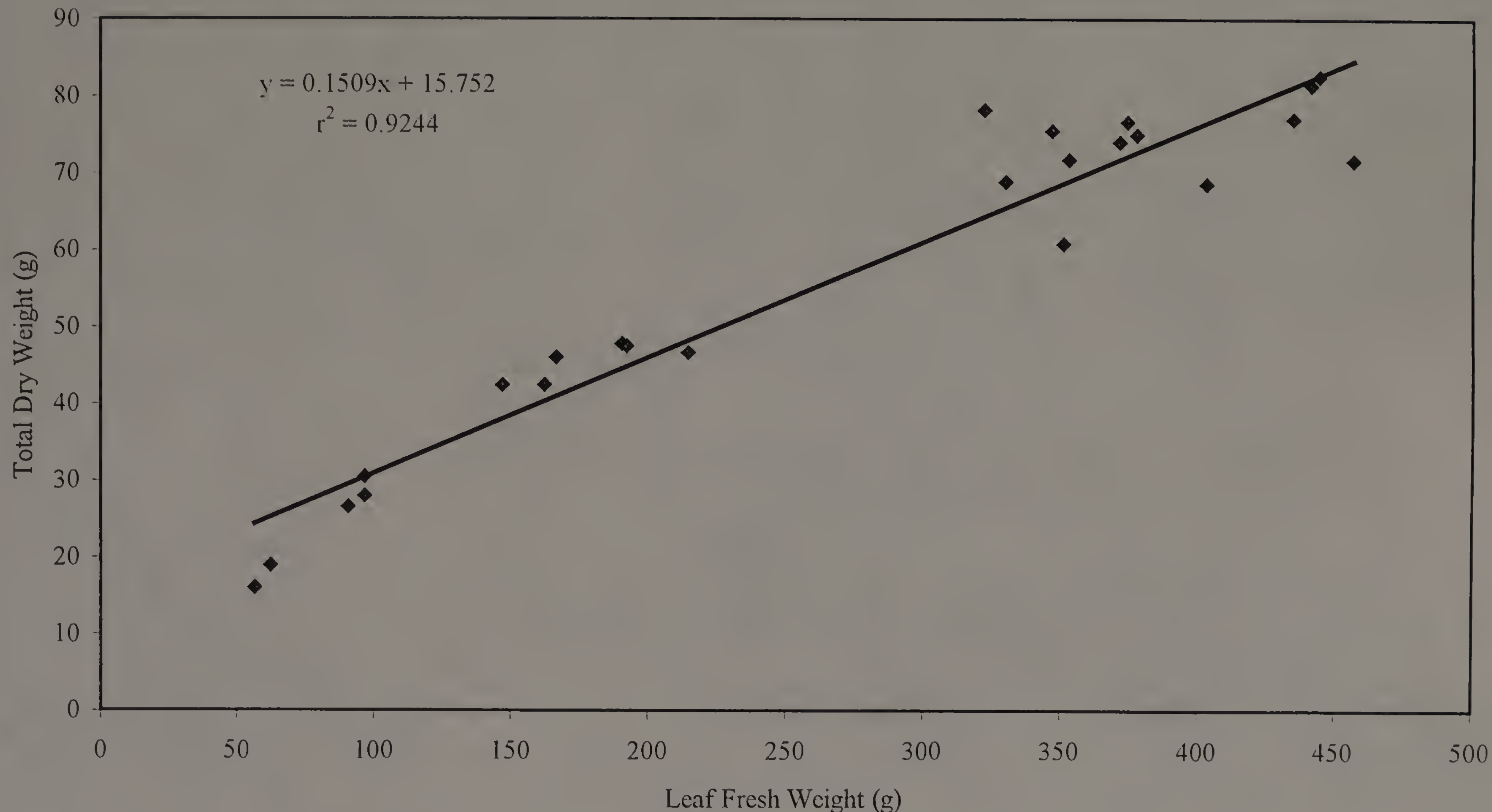


Figure 2.5 Relationship between Leaf Fresh Weight and Total Dry Weight for 1st Experiment

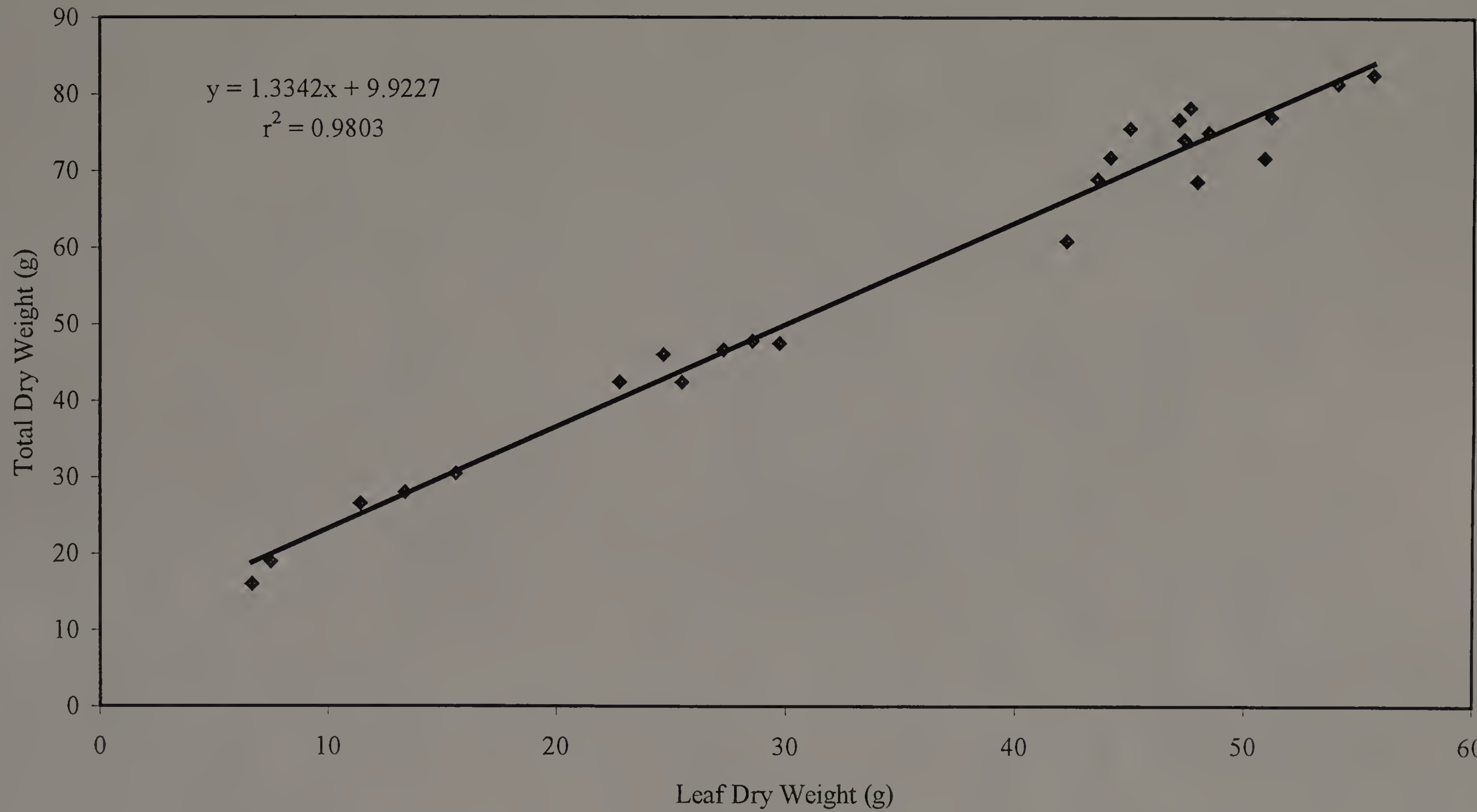


Figure 2.6 Relationship between Leaf Dry Weight and Total Dry Weight for 1st Experiment

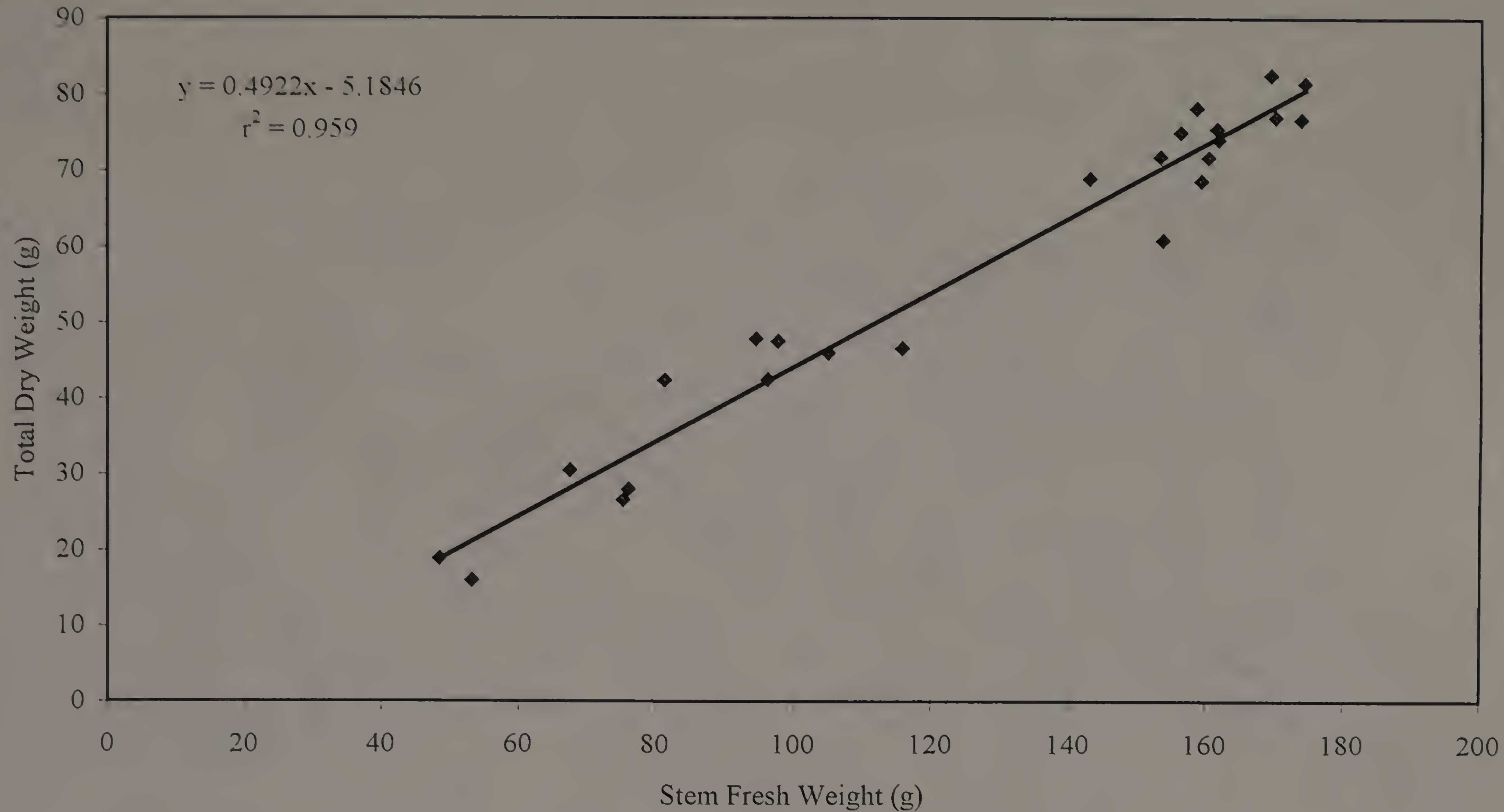


Figure 2.7 Relationship between Stem Fresh Weight and Total Dry Weight for 1st Experiment

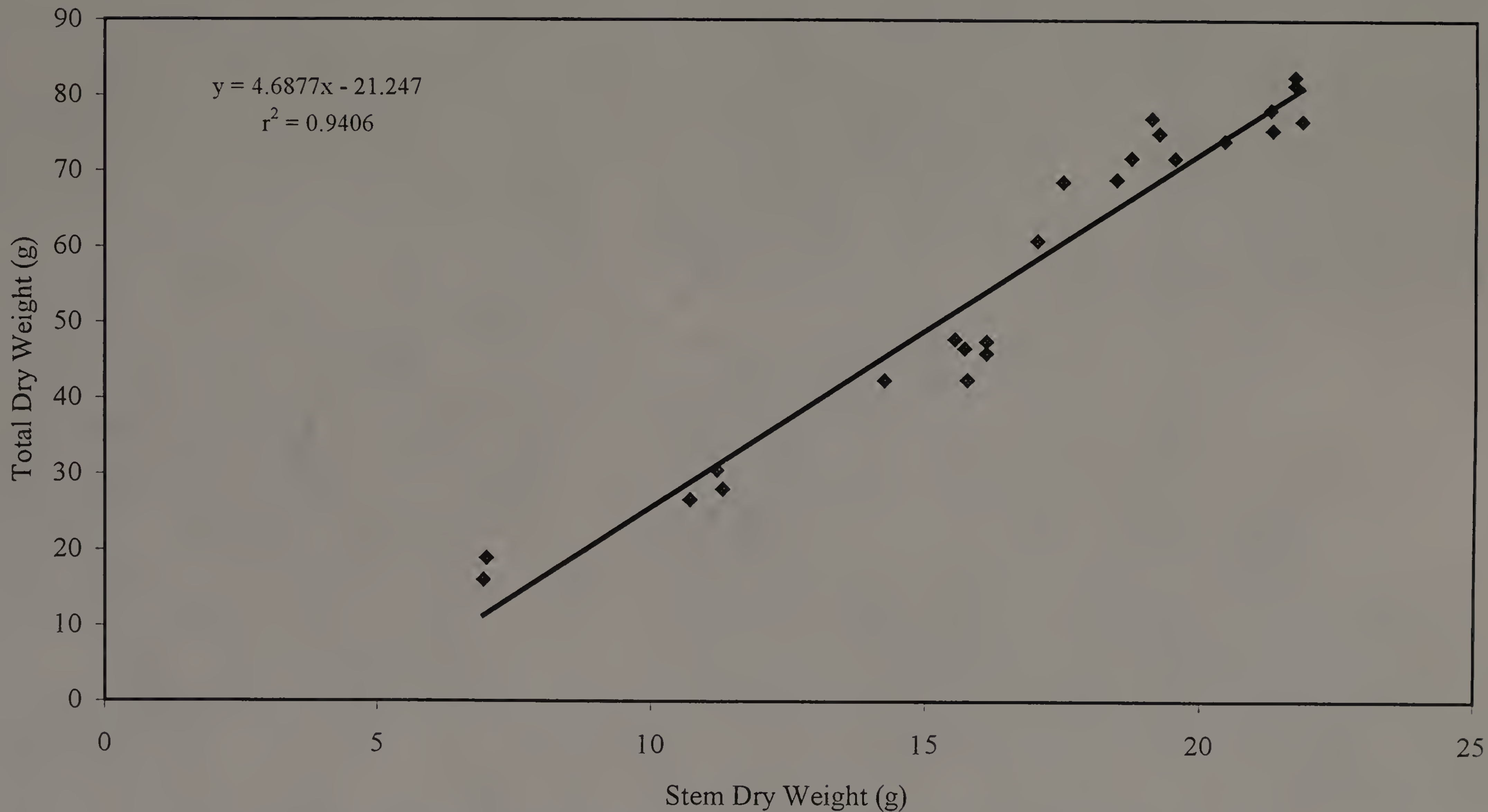


Figure 2.8 Relationship between Stem Dry Weight and Total Dry Weight for 1st Experiment

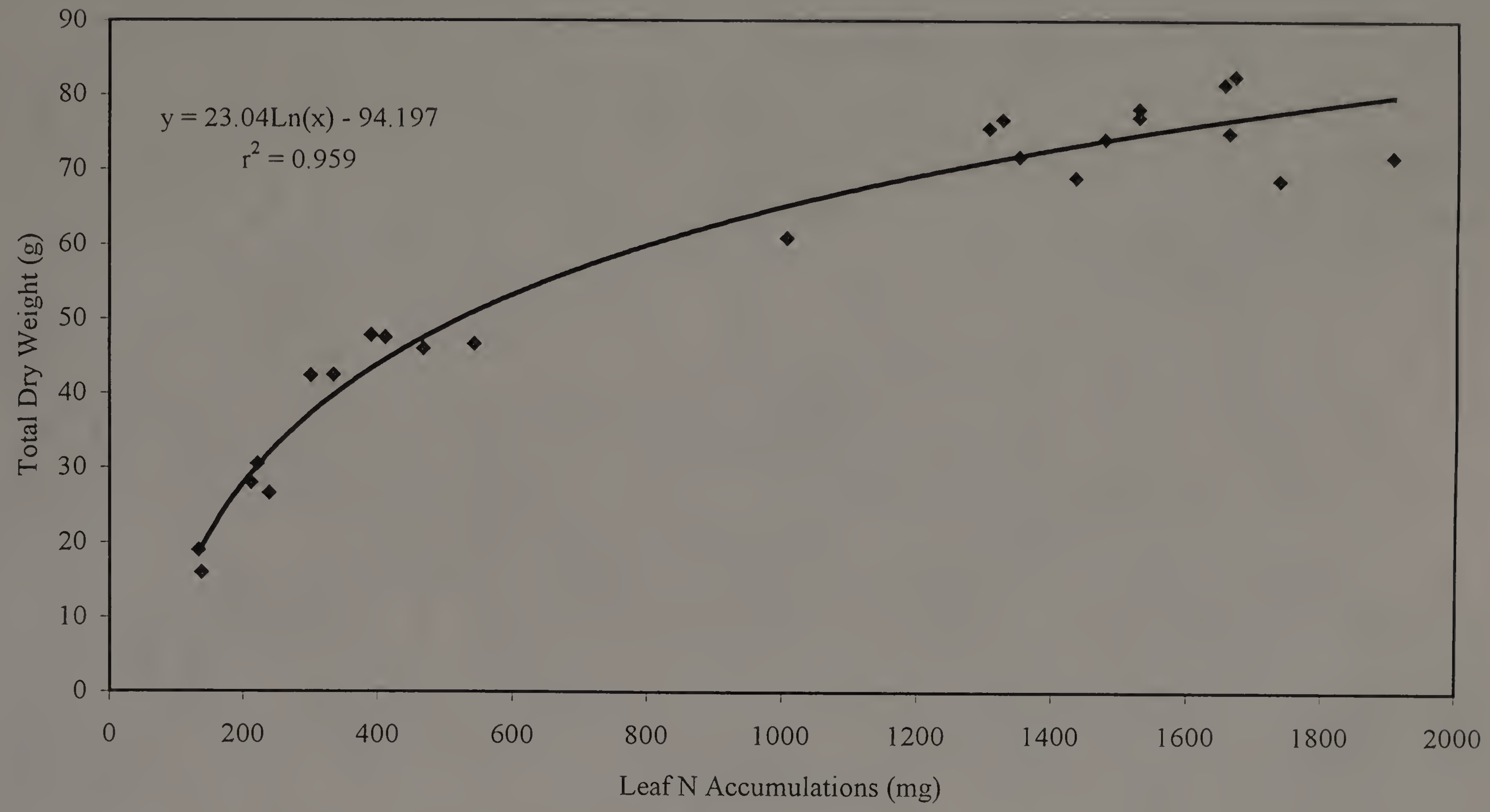


Figure 2.9 Relationship between Leaf N Accumulations and Total Dry Weight for 1st Experiment

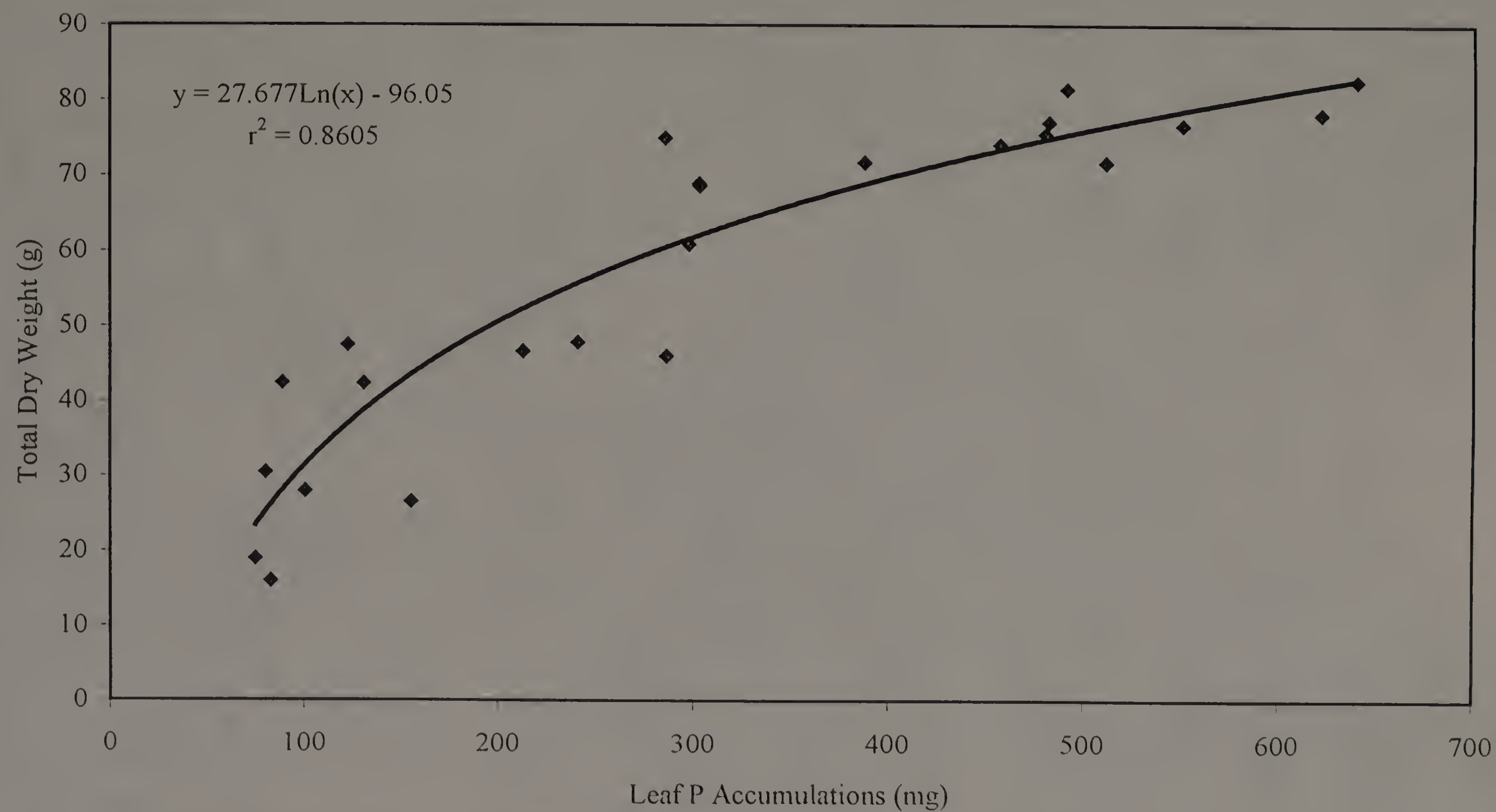


Figure 2.10 Relationship between Leaf P Accumulations and Total Dry Weight for 1st Experiment

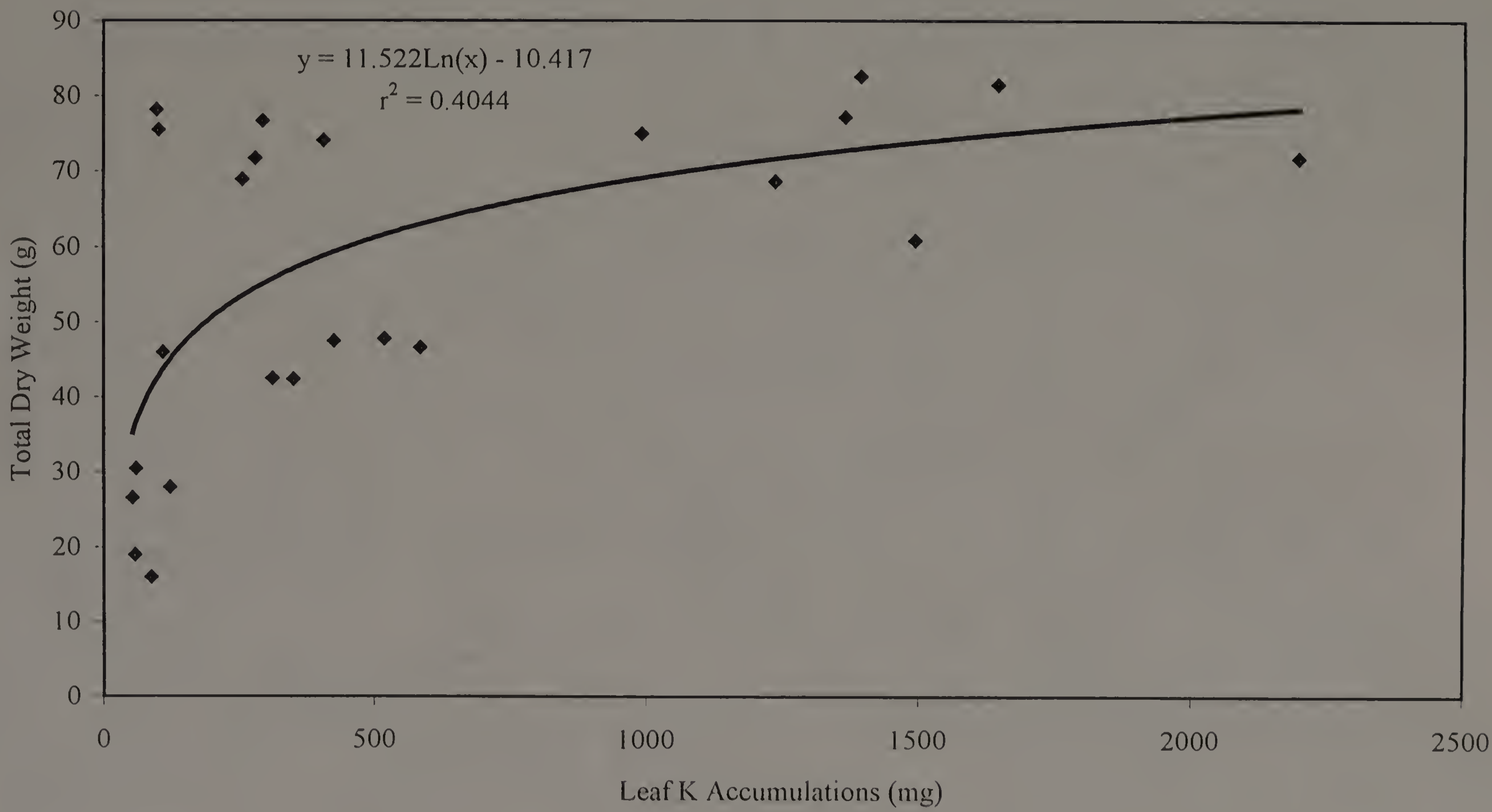


Figure 2.11 Relationship between Leaf K Accumulations and Total Dry Weight for 1st Experiment

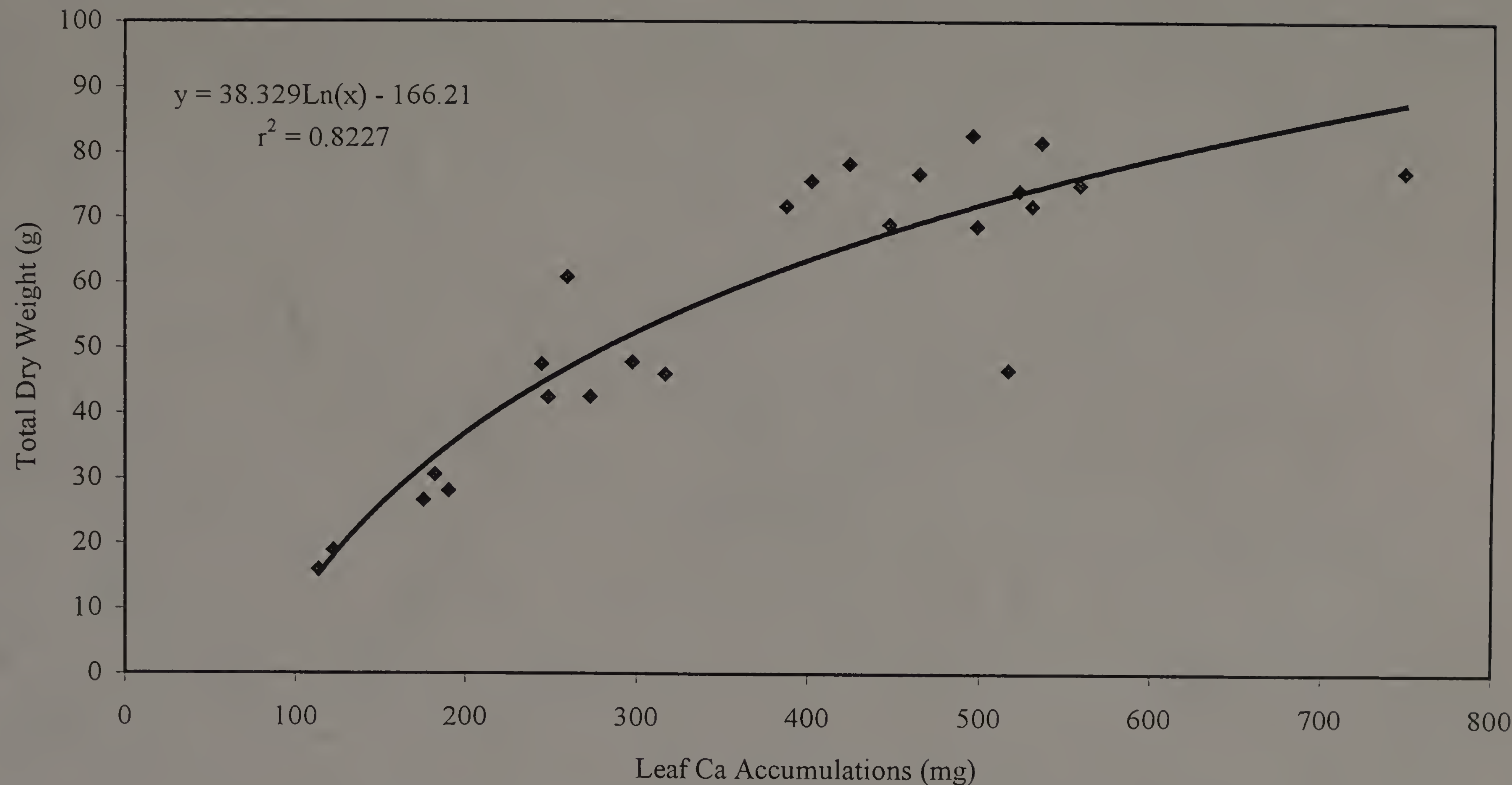
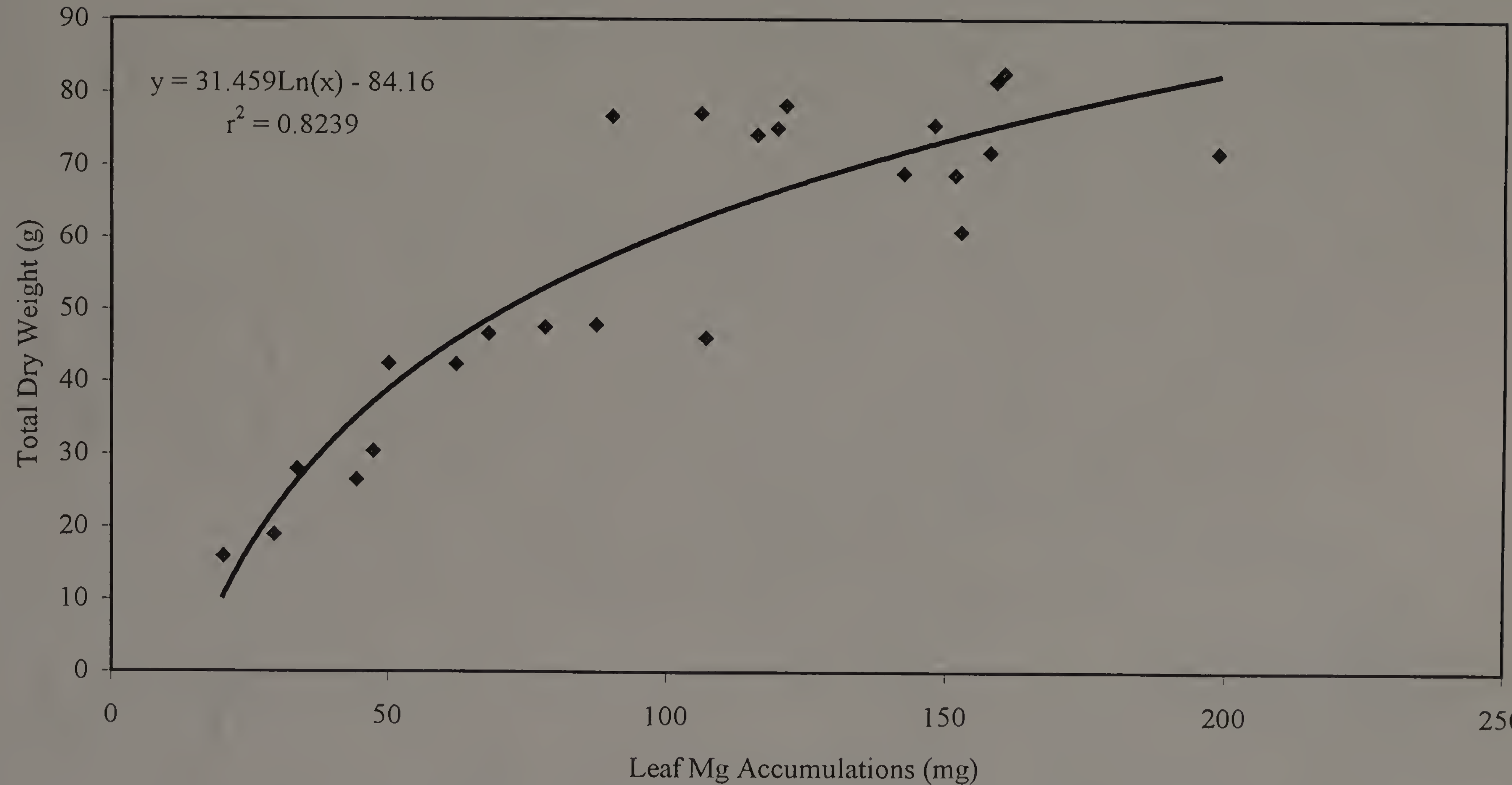


Figure 2.12 Relationship between Leaf Ca Accumulations and Total Dry Weight for 1st Experiment



Fugure 2.13 Relationship between Leaf Mg Accumulations and Total Dry Weight for 1st Experiment

CHAPTER 3

REDUCTION OF PHYTOTOXICITY OF IMMATURE COMPOST

3.1 Introduction

Uses of immature composts are often difficult due to their wide C:N ratio, high NH_4 content, and phytotoxins such as phenols and low molecular weight organic acids. Ammonium toxicity is common in immature composts made from N-rich substances (Wang et al., 1967; Chandrasekaran et al., 1973; Findenegg, 1987; He et al., 1992). Numerous studies have been done on effects of compost maturity on plant growth, microbiological parameters, nitrogen availability and other nutrient status (Keeling et al., 1995; Baca et al., 1995; Chanyasak et al., 1983 a, b). Several methods, such as carbon-based analysis, enzyme assays, molecular size determination, humification indicator, respiration measurement and phytotoxicity assays, have been suggested and are in use to evaluate compost maturity (Seekins, 1996; Blanco, 1994; Garcia et al., 1992; Inbar et al., 1990). Several criteria have been suggested for compost quality control especially for assessment of maturity (Forste, 1996; De Bertholdi et al., 1990; Manser and Keeling, 1996). Not too much literature addresses how to eliminate or reduce phytotoxicity of immature compost.

Reduction or elimination of phytotoxicity of immature compost caused by high NH_4 content was addressed in this research. This study worked with tomato plants and two composts for the purpose of comparing the effects of mature and immature composts on tomato growth and soil fertility and finding a practical means to avoid or reduce phytotoxicity of immature compost caused by high NH_4 content. This research focused on the toxicity caused by high NH_4 content because of its prevalence, its phytotoxicity at high concentration, its indication of compost immaturity, and ease of determination.

3.2 Materials and Methods

3.2.1 Materials

A compost of biosolids and wood chips was treated with $(NH_4)_2SO_4$ to 2,000 mg N kg^{-1} to simulate an immature compost. The same compost without any ammonium addition was used as mature compost. One soil and one peat moss were used as amendment materials. Again tomato plant (Lycopersicon esculentum Mill.) was employed as an indicator crop based the reasons mentioned in chapter 1.

Use of synthetic immature compost instead of a natural one was for quality control since as mentioned before so many factors can attribute to immaturity of composts and NH_4 can vary with time and handling in storage. Previous research has shown that 2,000 mg NH_4^+-N kg^{-1} is a common concentration in fresh immature compost (O'Brien and Barker, 1995).

3.2.2 Methods

In both composts, different proportions (regimes) of compost and soil were used at the ratios of 1:2, 1:5 and 1:11 compost:soil by volume to find a combination good for tomato growth and soil fertility. Each regime received potassium treatment at 0 or 0.6 g K kg^{-1} media as KCl, based on previous research that K has an ability to alleviate NH_4 toxicity by antagonism and promoting NH_4 assimilation. A nitrate treatment at 0 or 2,000 mg N kg^{-1} compost as $Ca(NO_3)_2$ was used, based on the fact that nitrate has been reported or suspected to lessen toxicity of NH_4. Tomato grew in the greenhouse for about six weeks from seedling until fruit initiation. The growth indices such as plant height, numbers of flower, fruit, leaf, and fresh and dry weights of fruit, leaf, and stem were recorded. Growth indices were used as criteria for evaluating the method to reduce or eliminate the phytotoxicity caused by high NH_4 content. Dried plant samples were ground to pass 40 mesh, digested and analyzed with same methods mentioned in the section of 2.2.2, and soil samples were prepared and analyzed with the same methods mentioned in the section of 2.2.2 for N, P, K, Ca, and Mg analysis. The analyses were used to help to evaluate the method of elimination or reduction of phytotoxicity caused by high NH_4 content in immature compost.

3.3 Results

3.3.1 Effects of Immature Compost on Tomato Growth

Tables 3.1, Table 3.2 and Table 3.3 provide information about the effects of immature compost on tomato growth. Eleven growth indices were measured, including plant height, numbers of flower, fruit and leaf, fresh and dry weights of fruit, leaf and stem, and total dry weight.

3.3.1.1 Tomato Plant Height

3.3.1.1.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between two compost media (Table 3.1). The mature compost medium generated much taller plants averaging 94 cm, and the immature medium produced an average height of 89 cm.

However, all regimes (proportions of compost) showed no overall significant differences (Table 3.1). The average heights were 91 cm, ranging from 90 to 93 cm.

No significant differences existed among the fertilization treatments (Table 3.1). The average plant heights were 88 cm for the treatment with NO_3 addition, 91 cm for the treatment without NO_3 addition, and 93 cm for the treatments with K addition or without K addition.

When the two different compost media were analyzed separately, some interactions were revealed in individual compost medium. The interaction was expressed as some treatments produced opposite results in the mature and immature compost media. For example, the treatment without NO_3 addition basically depressed plant growth in the immature compost medium, but it generally increased plant growth in the mature compost medium, which resulted in no overall significant differences (Table 3.3).

The interactive effects of the mature and immature compost media with the other factors were analyzed in the following sections.

3.3.1.1.2 Analysis of Effects of the Mature Compost Medium

There were differences in plant heights in the mature compost medium (Table 3.2). The regime of high proportion of compost (1:2) produced the tallest plant, averaging 98 cm. It followed by the medium proportion (1:5) that produced an average height of 93 cm. The low proportion (1:11) generated an average height of 92 cm.

Fertilization made no significant difference among the plant heights in the mature compost medium (Table 3.2). The average height was 94 cm, ranging from 93 to 96 cm.

In the mature compost medium, the NO_3 addition decreased plant height by 2.5% in the regime of low proportion of compost. It did not change plant height in the medium proportion, but increased plant height by 0.7% in the high proportion (Table 3.3).

In the mature compost medium, the treatment with K addition suppressed plant heights (Table 3.3). The decreases were by 3.2% in the regime of low proportion of compost, by 3.0% in the medium proportion, and by 1.7% in the high proportion.

3.3.1.1.3 Analysis of Effects of the Immature Compost Medium

There were some differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the tallest plant, with an average of 94 cm. It followed by the low proportion that produced an average height of 88 cm. The high proportion generated an average height of 84 cm.

Fertilization made some differences in the immature compost medium (Table 3.2). The K addition produced the tallest plant averaging 93 cm. The treatments without K and without NO_3 addition statistically produced the same plant height, averaging 89 cm. The treatment with NO_3 addition produced the shortest plants, averaging 82 cm.

In the immature compost medium, NO_3 addition suppressed plant height by 0.2% in the low proportion of compost and by 22.5% in the high proportion. However, NO_3 addition increased plant height by 0.9% in the medium proportion (Table 3.3).

In the immature compost medium, K addition suppressed plant height by 6.2% in the low proportion of compost. However it increased plant height by 10.5% in the medium proportion, and by 6.0% in the high proportion (Table 3.3).

3.3.1.2 Tomato Flower Numbers

3.3.1.2.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium yielded significantly higher numbers of flower than the mature compost medium, with averages of 62 and 45, respectively.

No overall significant differences existed among the regimes. The average numbers of flower were 54, ranging from 50 to 57 (Table 3.1).

No overall significant differences occurred among the fertilization treatments. The average numbers of flower were 54, ranging from 52 to 57 (Table 3.1).

The interactive effects of the mature and immature compost media with the other factors were analyzed and presented in the following sections.

3.3.1.2.2 Analysis of Effects of the Mature Compost Medium

All the regimes statistically produced the same numbers of flower in the mature compost medium, averaging 45 (Table 3.2).

Fertilization produced some differences in the mature compost medium (Table 3.2). The NO_3 addition produced the highest numbers of flower, averaging 56. The treatments without K and without NO_3 addition statistically produced the same numbers of flower, averaging 43. The treatment with K addition produced the least numbers of flower, averaging 37.

In the mature compost medium, all regimes with NO_3 addition increased numbers of flower (Table 3.3). The increases were by 43.9% in the low proportion, by 31.2% in the medium proportion and by 11.3% in the high proportion of compost.

However, the regimes with K addition showed different results in the mature compost medium. The K addition increased numbers of flower by 23.0% in the medium proportion. Otherwise it decreased the numbers of flower by 7.0% in the low proportion and by 39.3% in the high proportion of compost (Table 3.3).

3.3.1.2.3 Analysis of Effects of the Immature Compost Medium

There were some differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the highest numbers of flower, averaging 70. The low proportion produced the least amount of flower, averaging 54. The high proportion produced an average of 63 flowers per plant.

Fertilization also introduced some differences in the immature compost medium (Table 3.2). The treatments with K or without NO_3 addition statistically produced the same highest numbers of flower, averaging 71. The treatment with NO_3 addition produced the least amount of flower, averaging 46. The treatment without K addition produced flowers with an average of 61.

In the immature compost medium, the treatment with NO_3 addition decreased numbers of flower (Table 3.3). The decrease rate increased with more immature compost added. The numbers of flower decreased by 18.5% in the low proportion of compost, by 24.4% in the medium proportion, and by 60.0% in the high proportion.

In the immature compost medium, K addition reduced the numbers of flower by 13.1% in the low proportion of compost. However it increased the numbers of flower by 13.3% in the medium proportion, and by 48.4% in the high proportion. The more immature compost used, the higher increase rate with K addition (Table 3.3).

3.3.1.3 Tomato Fruit Numbers

3.3.1.3.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced average 5.8 fruits per plant, and the mature compost medium produced average 4.0.

There were some overall differences among the regimes (Table 3.1). The high proportion and medium proportion of compost statistically produced the same numbers of fruit, averaging 5.6 per plant. The low proportion produced the least amount of fruit, averaging 3.8.

Fertilization showed no overall significant differences (Table 3.1). The average was 5.0 fruits per plant, ranging from 3.9 to 5.5.

The interactive effects of the mature and immature compost media with the other factors were analyzed in the following sections.

3.3.1.3.2 Analysis of Effects of the Mature Compost Medium

There were some differences among the regimes in the mature compost medium (Table 3.2). The high proportion of compost produced the highest amount of fruit, averaging 4.6 fruits per plant. The medium proportion produced average 4.3 fruits. The low proportion produced the least amount of fruit, averaging 3.2 per plant.

There were some differences among fertilization treatments in the mature compost medium (Table 3.2). The treatment with NO_3 addition produced the highest amount of fruit, averaging 6.6 per plant. All others statistically produced the same numbers of fruit, averaging 3.2 and ranging from 2.8 to 3.6 fruits per plant.

All of the regimes with NO_3 addition increased numbers of fruit in the mature compost medium (Table 3.3). The increases were by 60.6% in the low proportion of compost, by 46.5% in the medium proportion and by 152% in the high proportion.

All of the regimes with K addition increased numbers of fruit in the mature compost medium (Table 3.3). The increases were by 131% in the low proportion of compost, by 60.0% in the medium proportion and by 33.3% in the high proportion.

3.3.1.3.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.2). The high proportion of compost produced the highest amount of fruit, averaging 6.9 per plant. The low proportion produced the least amount of fruit, averaging 4.3. The medium proportion produced an average of 6.3 fruits per plant.

There were no statistical differences among fertilization treatments in the immature compost medium (Table 3.2). The average numbers of fruit were 5.8, ranging from 4.3 to 6.8 fruits per plant.

In the immature compost medium, all regimes with NO_3 addition decreased the numbers of fruit (Table 3.3). The decreases were by 9.4% in the low proportion of compost, by 41.2% in the medium proportion and by 45.0% in the high proportion.

In the immature compost medium, K addition decreased the numbers of fruit by 37.8% in the low proportion of compost. However it increased the numbers of fruit by 41.7% in the medium proportion and by 46.7% in the high proportion (Table 3.3).

3.3.1.4 Tomato Fruit Fresh Weight

3.3.1.4.1 Analysis of Overall Effects of the Two Compost Media

No significant difference existed between the mature and immature compost media (Table 3.1). The average fresh fruit weight per plant was 89 g.

No statistical differences existed among the regimes (Table 3.1). The average was 89 g of fresh fruit per plant, ranging from 73 to 100 g per plant.

No statistical differences existed among the fertilization treatments (Table 3.1). The average was 89 g, ranging from 70 to 105 g per plant.

3.3.1.4.2 Analysis of Effects of the Mature Compost Medium

There were some differences among the regimes in the mature compost medium (Table 3.2). The high proportion of compost produced the highest amount of fresh fruit, averaging 112 g per plant. The low proportion produced the least amount of fresh fruit, averaging 60g. The medium proportion produced an intermediate average of 93 g.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 3.2). The average was 89 g, ranging from 60 to 111 g per plant.

In the mature compost medium, NO_3 addition slightly decreased fruit fresh weight by 0.9% in the low proportion of compost. Otherwise it increased the fruit fresh weight by 133% in the medium proportion and by 3.7% in the high proportion (Table 3.3).

In the mature compost medium, all regimes with K addition increased fruit fresh weight (Table 3.3). The increases were by 11.1% in the low proportion of compost, by 42.5% in the medium proportion and by 154% in the high proportion.

3.3.1.4.3 Analysis of Effects of the Immature Compost Medium

No significant differences existed among regimes in the immature compost medium (Table 3.2). The average was 89 g fresh fruit, ranging from 85 to 94 g per plant.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 3.2). The average was 89 g, ranging from 62 to 125 g per plant.

In the immature compost medium, the NO_3 addition decreased the fruit fresh weight in all three regimes (Table 3.3). The more immature compost was used, the higher the decrease was. The decreases were by 10.8% in the low proportion of compost, by 56.6% in the medium proportion and by 68.1% in the high proportion.

In the immature compost medium, the K addition decreased the fruit fresh weight by 22.8% in the low proportion of compost. However, it increased the fruit fresh weight by 45.4% in medium proportion and by 35.8% in the high proportion (Table 3.3).

3.3.1.5 Tomato Fruit Dry Weight

3.3.1.5.1 Analysis of Overall Effects of the Two Compost Media

The fruit dry weight followed the same trends of the fresh fruit weight.

There was no overall significant difference between the mature and immature compost media (Table 3.1). The average was 5.3 g, ranging from 5.1 to 5.4 g per plant.

There were no overall significant differences among the regimes (Table 3.1). The average was 5.2 g, ranging from 4.3 to 6.0 g per plant.

There were no overall significant differences among the fertilization treatments (Table 3.1). The average was 5.2 g, ranging from 4.3 to 6.0 g per plant.

3.3.1.5.2 Analysis of Effects of the Mature Compost Medium

There were differences among the regimes in the mature compost medium (Table 3.2). The high proportion of compost produced the highest amount of dry fruit, averaging 6.4 g. The low proportion produced the least amount of dry fruit, averaging 3.7 g. The medium proportion produced an intermediate average of 5.2 g.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 3.2). The average was 5.1 g, ranging from 3.9 to 5.9 g per plant.

In the mature compost medium, NO_3 addition decreased fruit dry weight by 5.7% in the low proportion of compost. Otherwise it increased the fruit dry weight by 75.0% in the medium proportion and by 5.6% in the high proportion (Table 3.3).

All of the regimes with K addition increased fruit dry weight in the mature compost medium (Table 3.3). The increases were by 7.7% in the low proportion of compost, by 12.8% in the medium proportion and by 157% in the high proportion.

3.3.1.5.3 Analysis of Effects of the Immature Compost Medium

No significant differences existed among the regimes in the immature compost medium (Table 3.2). The average was 5.4 g, ranging from 4.9 to 5.6 g per plant.

No significant differences existed among fertilization treatments in the immature compost medium (Table 3.2). The average was 5.4 g, ranging from 3.9 to 7.1 g per plant.

In the immature compost medium, the NO_3 addition decreased the fruit dry weight in all three regimes (Table 3.3). The more immature compost was used, the higher the decrease rate was. The decreases were by 14.6% in the low proportion of compost, by 48.5% in the medium proportion and by 61.2% in the high proportion.

In the immature compost medium, the K addition decreased the fruit dry weight by 8.8% in the low proportion of compost. However, it increased the fruit dry weight by 67.9% in the medium proportion and by 32.1% in the high proportion (Table 3.3).

3.3.1.6 Tomato Leaf Numbers

3.3.1.6.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced average 46 leaves per plant, and the mature compost medium produced an average of 35.

There were no significant differences among the regimes (Table 3.1). The average was 40 leaves per plant, ranging from 39 to 41.

There were no significant differences among the fertilization treatments (Table 3.1). They produced an average of 40 leaves per plant, ranging from 39 to 42.

3.3.1.6.2 Analysis of Effects of the Mature Compost Medium

No significant differences existed among the regimes in the mature compost medium (Table 3.2). The average was 35 leaves, ranging from 33 to 37 per plant.

There were differences among the fertilization treatments in the mature compost medium (Table 3.2). The NO_3 addition produced the highest amount of leaves with an average of 42. All other fertilization treatments statistically had same numbers of leaf, averaging 33 leaves and ranging from 30 to 35 per plant.

In the mature compost medium, all regimes with NO_3 addition increased the numbers of leaf (Table 3.3). The increases were by 12.9% in the low proportion of compost, by 51.7% in the medium proportion and by 8.7% in the high proportion.

In the mature compost medium, all the regimes with K addition decreased numbers of leaf (Table 3.3). The decreases were by 12.3% in the low proportion of compost, by 8.7% in the medium proportion and by 22.8% in the high proportion.

3.3.1.6.3 Analysis of Effects of the Immature Compost Medium

No significant differences existed among the regimes in the immature compost medium (Table 3.2). The average was 46 leaves, ranging from 42 to 48 per plant.

There were differences among the fertilization treatments in the immature compost medium (Table 3.2). The treatments without NO_3 addition and with K addition statistically produced the same numbers of leaf, averaging 50. The treatment with NO_3 addition produced the least amount of the numbers of leaf, averaging 38. The treatment without K addition produced an average of 46 leaves per plant.

In the immature compost medium, all regimes with NO_3 addition decreased the numbers of leaf (Table 3.3). The decreases were by 13.5% in the low proportion of compost, by 2.1% in the medium proportion and by 50.0% in the high proportion.

In the immature compost medium, the K addition decreased the numbers of leaf by 23.1% in the low proportion of compost. However, it increased the numbers of leaf by 6.8% in the medium proportion and by 36.2% in the high proportion (Table 3.3).

3.3.1.7 Tomato Leaf Fresh Weight

3.3.1.7.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.1). The immature compost medium produced leaf fresh weight with an average of 199 g per plant, and the mature medium produced an average of 130 g.

There were differences among the regimes (Tables 3.1). The medium proportion and high proportion of compost statistically produced the same weights of fresh leaf, averaging 175 g per plant. The low proportion produced an average of 143 g.

There were no overall significant differences among fertilization treatments (Table 3.1). The average weights of fresh leaf were 165 g, ranging from 157 to 180 g per plant.

3.3.1.7.2 Analysis of Effects of the Mature Compost Medium

No significant differences existed among the regimes in the mature compost medium (Table 3.2). The average was 130 g, ranging from 123 to 142 g per plant.

There were differences among the fertilization treatments in the mature compost medium (Table 3.2). The addition of NO_3 produced the highest weights of fresh leaf, averaging 179 g. The treatment without NO_3 addition produced an average of 133 g.

The treatment without K addition produced an average of 117 g. The treatment with K addition produced the least weight of fresh leaf, averaging 90 g per plant.

In the mature compost medium, all regimes with NO_3 addition increased the leaf fresh weight (Table 3.3). The increases were by 32.5% in the low proportion of compost, by 50.7% in the medium proportion and by 21.2% in the high proportion.

In the mature compost medium, all regimes with K addition decreased the leaf fresh weight (Table 3.3). The decreases were by 30.6% in the low proportion of compost, by 0.5% in the medium proportion and by 33.3% in the high proportion.

3.3.1.7.3 Analysis of Effects of the Immature Compost Medium

Differences existed among the regimes in the immature compost medium (Table 3.2). The medium proportion and high proportion of compost statistically produced the same weight of fresh leaf, averaging 219 g per plant. The low proportion produced an average of 161 g.

There were differences among the fertilization treatments in the immature compost medium (Table 3.2). The treatments without NO_3 addition, with K addition, and without K addition statistically produced the same weight of fresh leaf, averaging 221 g per plant and ranging from 210 g to 227 g per plant. The treatment with NO_3 addition produced the least weight of fresh leaf, averaging 135 g.

In the immature compost medium, all regimes with NO_3 addition decreased the leaf fresh weight (Table 3.3). The decreases were by 25.4% in the low proportion of compost, by 11.8% in the medium proportion and by 75.1% in the high proportion.

In the immature compost medium, the K addition decreased the leaf fresh weight by 28.8% in the low proportion of compost. However it increased the leaf fresh weight by 13.8% in the medium proportion and by 33.6% in the high proportion (Table 3.3).

3.3.1.8 Tomato Leaf Dry Weight

Leaf dry weight followed the same trends of leaf fresh weight.

3.3.1.8.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced leaf dry weight with an average of 25.9 g, and the mature medium produced an average of 17.2 g.

There were differences among the regimes (Table 3.1). The medium proportion of compost produced the highest weight of dry leaf, averaging 22.9 g, The high proportion of compost produced the second highest weight of dry leaf, averaging 22.5 g, the low proportion produced an average of 19.4 g.

There were differences among the fertilization treatments (Table 3.1). The treatment without NO_3 addition produced the highest dry leaf weight, averaging 24.1 g. The treatment with K addition produced an average of 19.8 g. The treatments without K and with NO_3 addition statistically produced the same dry leaf weight, averaging 21.2 g.

3.3.1.8.2 Analysis of Effects of the Mature Compost Medium

No significant differences existed among the regimes in the mature compost medium (Table 3.2). The average was 17 g, ranging from 16 to 19 g per plant.

There were some differences among the fertilization treatments in the mature compost medium (Table 3.2). The treatment with NO_3 addition produced the highest leaf dry weight, averaging 24 g per plant. The treatment without NO_3 addition produced the second highest leaf dry weight, averaging 18 g. The treatment without K addition produced an average of 16 g. The treatment with K addition produced the least leaf dry weight, averaging 11 g.

In the mature compost medium, all regimes with NO_3 addition increased the leaf dry weight (Table 3.3). The increases were by 26.1% in the low proportion of compost, by 49.7% in the medium proportion and by 24.7% in the high proportion.

In the mature compost medium, all regimes with K addition decreased the leaf dry weight (Table 3.3). The decreases were by 40.5% in the low proportion of compost, by 6.3% in the medium proportion and by 36.0% in the high proportion.

3.3.1.8.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the highest leaf dry weight, averaging 29.6 g per plant. The low proportion produced an average of 21.8 g. The high proportion produced an average of 26.4 g.

There were differences among the fertilization treatments in the immature compost medium (Table 3.2). The treatments without NO_3 addition, with K addition and without K addition statistically produced the same leaf dry weight, averaging 28.7 g and ranging from 27.5 to 30.2 g. The treatment with NO_3 addition produced the least leaf dry weight, averaging 17.7 g per plant.

In the immature compost medium, all the regimes with NO_3 addition decreased leaf dry weight (Table 3.3). The decreases were by 29.5% in the low proportion of compost, by 15.7% in the medium proportion and by 72.5% in the high proportion.

In the immature compost medium, the K addition decreased the leaf dry weight by 34.8% in the low proportion of compost. However, it increased the leaf dry weight by 9.9% in the medium proportion and by 32.6% in the high proportion (Table 3.3).

3.3.1.9 Tomato Stem Fresh Weight

3.3.1.9.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced stem fresh weight with an average of 129 g, and the mature medium produced an average of 106 g.

There were no overall significant differences among the regimes (Table 3.1). The average stem fresh weight was 117 g, ranging from 110 to 126 g per plant.

There were no overall significant differences among the fertilization treatments (Table 3.1). The averages were 118 g. ranging from 106 to 124 g per plant.

3.3.1.9.2 Analysis of Effects of the Mature Compost Medium

No significant differences existed among the regimes in the mature compost medium (Table 3.2). The average was 106 g, ranging from 102 to 112 g per plant.

There were differences among the fertilization treatments in the mature compost medium (Table 3.2). The treatment with NO_3 addition produced the highest stem fresh weight, averaging 124 g. The treatment with K addition produced the least stem fresh weight, averaging 88 g. The treatments without NO_3 and without K addition statistically produced the same stem fresh weight, averaging 106 g per plant.

In the mature compost medium, all regimes with NO_3 addition increased stem fresh weight (Table 3.3). The increases were by 9.1% in the low proportion of compost, by 33.1% in the medium proportion and by 2.1% in the high proportion.

In the mature compost medium, all regimes with K addition decreased the stem fresh weight (Table 3.3). The decreases were by 7.3% in the low proportion of compost, by 6.6% in the medium proportion and by 34.6% in the high proportion.

3.3.1.9.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the highest stem fresh weight, averaging 151 g per plant. The high proportion and low proportion statistically produced the same stem fresh weight, averaging 118 g per plant.

There were differences among the fertilization treatments in the immature compost medium (Table 3.2). The regimes with K, without NO_3 and without K addition statistically produced the same stem fresh weight, averaging 143 g and ranging from 137 to 153 g per plant. The treatment with NO_3 addition produced the least stem fresh weight, averaging 88 g per plant.

In the immature compost medium, all regimes with NO_3 addition decreased the stem fresh weight (Table 3.3). The decreases were by 19.6% in the low proportion of compost, by 17.5% in the medium proportion and by 68.3% in the high proportion.

In the immature compost medium, the regime with K addition decreased the stem fresh weight by 21.5% in the low proportion of compost. However, it increased the stem fresh weight by 16.4% in the medium proportion and by 41.5% in the high proportion (Table 3.3).

3.3.1.10 Tomato Stem Dry Weight

The stem dry weight followed the same trends of stem fresh weight.

3.3.1.10.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced an average of 17.9 g dry stem per plant, and the mature medium produced an average of 15.6 g.

There were no overall significant differences among regimes (Table 3.1). The average was 16.8 g of dry stem, ranging from 16.2 to 17.6 g per plant.

There were overall differences among fertilization treatments (Table 3.1). The treatments without NO_3 and without K addition statistically produced the same stem dry weight, averaging 17.8 g per plant. The treatment with NO_3 addition produced the least stem dry weight, averaging 14.8 g. The treatment with K addition produced an average of 17.0 g.

3.3.1.10.2 Analysis of Effects of the Mature Compost Medium

No significant differences existed among the regimes in the mature compost medium (Table 3.2). The average was 15.6 g, ranging from14.8 to 16.1 g per plant.

There were also no significant differences among fertilization treatments in the mature compost medium (Table 3.2). The averages were 16.8 g of dry stem in the treatment without NO_3 addition, 16.4 g in the treatment with NO_3 addition, 16.1 g in the treatment without K addition and 13.3 g in the treatment with K addition.

In the mature compost medium, all the regimes with NO_3 addition increased the stem dry weight (Table 3.3). The increases were by 5.4% in the low proportion of compost, by 12.0% in the medium proportion and by 14.4% in the high proportion.

In the mature compost medium, all the regimes with K addition decreased stem dry weight (Table 3.3). The decreases were by 15.6% in the low proportion of compost, by 6.3% in the medium proportion and by 34.1% in the high proportion.

3.3.1.10.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the highest stem dry weight, averaging 20.3 g per plant. The high proportion produced the least stem dry weight, averaging 16.3 g. The low proportion produced an intermediate average of 17.1 g.

Differences existed among fertilization treatments in the immature compost medium (Table 3.2). The treatments with K, without NO_3 and without K addition statistically produced the same stem dry weight, averaging 19.8 g. The treatment with NO_3 addition produced the least stem dry weight, averaging 12.2 g per plant.

In the immature compost medium, all the regimes with NO_3 addition decreased the stem dry weight (Table 3.3). The decreases were by 24.9% in the low proportion of compost, by 22.1% in the medium proportion and by 66.8% in the high proportion.

In the immature compost medium, the K addition in the low proportion of compost decreased stem dry weight by 24.5%. However it increased stem dry weight by 14.8% in the medium proportion and by 43.1% in the high proportion (Table 3.3).

3.3.1.11 Tomato Total Dry Weight

3.3.1.11.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and the immature compost media (Table 3.1). The immature compost medium produced an average of 49.3 g of total dry weight per plant, and the mature medium produced an average of 37.9 g.

There were no overall significant differences among three regimes (Table 3.1). The average was 43.6 g per plant, ranging from 40.3 to 45.9 g.

There were overall differences among fertilization treatments (Table 3.1). The treatment without NO_3 addition produced the highest total dry weight, averaging 47.9 g per plant. The treatment with NO_3 addition produced the least total dry weight, averaging 40.6 g. The treatments without K and with K addition statistically produced the same total dry weight, averaging 43.0 g per plant.

3.3.1.11.2 Analysis of Effects of the Mature Compost Medium

There were no significant differences among the regimes in the mature compost medium (Table 3.2). The average was 38.0 g, ranging from 36.2 to 41.0 g per plant.

There were differences among the fertilization treatments in the mature compost medium (Table 3.2). The treatment with NO_3 addition produced the highest total dry weight, averaging 45.3 g per plant. The treatment with K addition produced the least total dry weight, averaging 30.4 g. The treatment without NO_3 addition produced an intermediate average of 40.7 g. The treatment without K addition produced an average of 35.4 g.

In the mature compost medium, all the regimes with NO_3 addition increased total dry weight (Table 3.3). The increases were by 14.5% in the low proportion of compost, by 36.4% in the medium proportion and by 17.1% in the high proportion.

In the mature compost medium, all the regimes with K addition decreased the total dry weight (Table 3.3). The decreases were by 23.5% in the low proportion of compost, by 3.5% in the medium proportion and by 22.4% in the high proportion.

3.3.1.11.3 Analysis of Effects of the Immature Compost Medium

There were some differences among the regimes in the immature compost medium (Table 3.2). The medium proportion of compost produced the highest total dry weight, averaging 55.6 g per plant. The low proportion produced the least total dry weight, averaging 43.8 g. The high proportion produced an average of 48.3 g.

There were differences among the fertilization treatments in the immature compost medium (Table 3.2). The treatments without NO_3, with K and without K addition statistically produced the same total dry weight, averaging 54.4 g and ranging from 51.2 g to 57.1 g per plant. The treatment with NO_3 addition produced the least total dry weight, averaging 33.8 g.

In the immature compost medium, all the regimes with NO_3 addition decreased the total dry weight (Table 3.3). The decreases were by 26.3% in the low proportion of compost, by 23.3% in the medium proportion and by 69.5% in the high proportion.

In the immature compost medium, the K addition decreased the total dry weight by 28.1% in the low proportion of compost. However it increased the total dry weight by 14.8% in the medium proportion and by 36.0% in the high proportion (Table 3.3).

3.3.1.12 Various Growth Index vs. Total Plant Dry Weight

Figures 3.1 to 3.7 show the relationship between each of most growth indices and total plant dry weight. Tests showed a significantly highly positive correlation between each of the most of growth indices and total plant dry weight.

Figure 3.1 shows the relationship between the numbers of flower and total dry weight, which carries a linear regression coefficient 0.89. Figure 3.2 shows the relationship between the numbers of fruit and total dry weight, which carries a linear regression coefficient 0.55. Figure 3.3 shows the relationship between the numbers of leaf and total dry weight, which carries a linear regression coefficient 0.89. Figure 3.4 shows the relationship between leaf fresh weight and total dry weight, which carries a linear regression coefficient 0.95. Figure 3.5 shows the relationship between leaf dry weight and total dry weight, which carries a linear regression coefficient 0.96. Figure 3.6 shows the relationship between stem fresh weight and total dry weight, which carries a linear regression coefficient 0.88. Figure 3.7 shows the relationship between stem dry weight and total dry weight, which carries a linear regression coefficient 0.85 (The tabulated linear regression coefficients are 0.515 at 0.01 level, 0.396 at 0.05 level when sample size n=24).

There was no significant correlation between plant height, fruit fresh weight, or fruit dry weight and total dry weight.

The results indicated that the vegetative parts of the plant were the major contributors to the total dry weight. Some of those parameters, especially the numbers of leaf and numbers of flower, could be used to predict plant production very well. Therefore destructive harvests could be avoided.

3.3.2 Effects of Immature Compost on Leaf Nutrient Accumulations

Tables 3.4, 3.5 and 3.6 provide the information of the leaf nutrient concentration and the total nutrient accumulations by plant leaves. There was highly significantly positive correlation between each of individual nutrient accumulation and total dry weight. Five nutrients were measured for leaf samples, including N, P, K, Ca, and Mg.

3.3.2.1 Nitrogen

3.3.2.1.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference in total N accumulation in tomato leaves between the mature and the immature compost media (Table 3.4). Plants in the immature compost medium accumulated an average of 805 mg N and accumulated 367 mg in the mature compost medium. On this basis the immature compost medium provided 119% more N than the mature compost medium.

There were no overall significant differences among the regimes (Table 3.4). The average was 586 mg N, ranging from 526 to 622 mg per plant.

There were no overall significant differences among the fertilizer treatments (Table 3.4). The average was 587 mg N, ranging from 553 to 614 mg per plant.

However, the interactions between different fertilization treatments and specific compost medium are presented in the following sections.

3.3.2.1.2 Analysis of Effects of the Mature Compost Medium

No statistical differences existed among the regimes in the mature compost medium (Table 3.5). The average N accumulation was 367 mg, ranging from 351 to 380 mg per plant.

There were statistical differences among the fertilization treatments in the mature compost medium (Table 3.5). The highest N accumulation in the leaves was in the treatment with NO_3 addition, averaging 607 mg. The second highest N accumulation in the leaves was in the treatment without K addition, averaging 365 mg. The treatment with K addition accumulated the least amount of N in the leaves, averaging 187 mg per plant. The treatment without NO_3 addition accumulated an average of 311mg N.

In the mature compost medium, all the regimes with NO_3 addition increased N accumulation in plant leaves (Table 3.6). Compared with the non-fertilized treatments, the increases were by 120% in the low proportion of compost, by 160% in the medium proportion and by 5.8% in the high proportion.

In the mature compost medium, all the regimes with K addition decreased N accumulation in plant leaves (Table 3.6). The decreases were by 38.0% in the low proportion of compost, by 6.2% in the medium proportion and by 66.6% in the high proportion.

3.3.2.1.3 Analysis of Effects of the Immature Compost Medium

Differences existed among the regimes in the immature compost medium (Table 3.5). The medium proportion of compost accumulated the highest amount of N in plant leaves, averaging 892 mg. The high proportion accumulated the second highest amount of N, averaging 852 mg. The low proportion accumulated the least amount of N, averaging 673 mg.

There were differences among the fertilization treatments in the immature compost medium (Table 3.5). The treatments without NO_3, with K, and without K addition statistically accumulated the same amount of N in plant leaves, averaging 908 mg and ranging from 862 to 954 mg per plant. The treatment with NO_3 addition accumulated the least amount of N, averaging 498 mg.

In the immature compost medium, basically there were opposite results compared with the mature compost medium with respect to N accumulation among the regimes.

In the immature compost medium, all the regimes with NO_3 addition decreased N accumulation in plant leaves (Table 3.6). The decreases were by 31.9% in the low proportion of compost, by 14.9% in the medium proportion and by 74.7% in the high proportion.

In the immature compost medium, the K addition decreased N accumulation by 33.0% in the low proportion of compost. However it increased N accumulation by 11.5% in the medium proportion and by 54.6% in the high proportion (Table 3.6).

3.3.2.2 Phosphorus

3.3.2.2.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.4). Plants in the immature compost medium accumulated an average of 78 mg P whereas those in the mature compost medium accumulated an average of 46 mg. On this basis, the immature compost medium provided 69.6% more P than the mature compost medium.

There were differences among the regimes (Table 3.4). The high proportion and medium proportion of compost statistically provided the same amount of P for plants, averaging 68 mg P accumulated. The low proportion provided an average of 51 mg P.

There were differences among the fertilization treatments (Table 3.4). The treatments with K or without K addition statistically provided the same amount of P for plants, averaging 73 mg P. The treatments without NO_3 or with NO_3 addition statistically provided the same amount of P, averaging 51 mg P accumulated.

3.3.2.2.2 Analysis of Effects of the Mature Compost Medium

No statistical differences existed among the regimes in the mature compost medium (Table 3.5). Plants accumulated an average of 46 mg P, ranging from 44 to 49 mg per plant.

There were no statistical differences among the fertilization treatments in the mature compost medium (Table 3.5). Plants accumulated an average of 46 mg P, ranging from 36 to 51 mg per plant.

In the mature compost medium, all the regimes with NO_3 addition increased P accumulation in plant leaves (Table 3.6). The increases were by 19.0% in the low proportion of compost, by 13.6% in the medium proportion and by 5.9% in the high proportion.

In the mature compost medium, all the regimes with K addition decreased P accumulation (Table 3.6). The decreases were by 55.5% in the low proportion of compost, by 7.5% in the medium proportion and by 24.5% in the high proportion.

3.3.2.2.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.5). The medium proportion and high proportion of compost statistically provided the same amount of P for plant, averaging 88 mg P per plant. The low proportion provided an average of 58 mg P.

There were differences among the fertilization treatments in the immature compost medium (Table 3.5). The treatments with K or without K addition statistically provided the same amount of P for plants, averaging 103 mg P accumulated per plant. The treatment without NO_3 addition provided an average of 68 mg P. The treatment with NO_3 addition accumulated an average of 39 mg P per plant.

In the immature compost medium, basically there were opposite results compared with the mature compost medium regarding the interactions.

In the immature compost medium, all the regimes with NO_3 addition decreased P accumulation (Table 3.6). The decreases were by 26.5% in the low proportion of compost, by 8.0% in the medium proportion and by 72.3% in the high proportion.

In the immature compost medium, the K addition decreased P accumulation by 35.4% in the low proportion of compost. However it increased P accumulation by 9.5% in the medium proportion and by 83.9% in the high proportion (Table 3.6).

3.3.2.3 Potassium

3.3.2.3.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.4). Plants in the mature compost medium accumulated an average of 342 mg K whereas plants in the immature compost medium accumulated an average of 215 mg. The mature compost medium provided 59.1% more K than the immature compost medium.

There were no overall differences among the regimes (Table 3.4). The average was 279 mg K accumulated, ranging from 263 to 310 mg per plant.

There were no overall significant differences among the fertilization treatments (Table 3.4). The average was 279 mg K accumulated, ranging from 242 to 314 mg per plant.

3.3.2.3.2 Analysis of Effects of the Mature Compost Medium

No statistical differences existed among the regimes in the mature compost medium (Table 3.5). Plants accumulated an average of 341 mg K, ranging from 323 to 372 mg per plant.

There were statistical differences among the fertilization treatments in the mature compost medium (Table 3.5). Plants in the treatment with NO_3 addition accumulated an average of 524 mg K. Plants in other three treatments statistically accumulated the same amount of K, averaging 281 mg and ranging from 235 to 344 mg per plant.

All the regimes with NO_3 addition increased K accumulations in the mature compost medium (Table 3.6). The increases were by 37.4% in the low proportion of compost, by 197% in the medium proportion and by 102% in the high proportion.

All the regimes with K addition decreased K accumulation in the mature compost medium (Table 3.6). The decreases were by 30.1% in the low proportion of compost, by 21.1% in the medium proportion and by 39.1% in the high proportion.

3.3.2.3.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.5). The low proportion and high proportion of compost statistically provided the same amount of K for plants, averaging 174 mg K accumulated. Plants in the medium proportion accumulated an average of 297 mg K.

There were differences among the fertilization treatments in the immature compost medium (Table 3.5). In the treatments without NO_3, with K, and without K addition, plants statistically accumulated the same amount of K, averaging 252 mg K per plant. Plants accumulated an average of 103 mg K in the treatment with NO_3 addition.

In the immature compost medium, basically there were opposite results compared with the mature compost medium regarding the interactions.

All the regimes with NO_3 addition decreased K accumulation in the immature compost medium (Table 3.6). The decreases were by 10.5% in the low proportion of compost, by 75.1% in the medium proportion and by 78.1% in the high proportion. The more immature compost was used, the higher the decrease rate would be.

In the immature compost medium, the K addition decreased K accumulation by 68.9% in the low proportion of compost. However it increased K accumulation by 135% in the medium proportion and by 156% in the high proportion (Table 3.6).

3.3.2.4 Calcium

3.3.2.4.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.4). Plants in the immature compost medium accumulated an average of 302 mg Ca whereas they accumulated an average of 227 mg Ca in the mature compost medium. The immature compost medium provided 33.0% more Ca than the mature compost medium.

There were differences among the regimes (Table 3.4). Plants accumulated the highest amount of Ca with an average of 317 mg in the high proportion of compost. Plants statistically accumulated the same amount of Ca in the medium proportion and low proportion of compost, averaging 238 mg Ca per plant.

There were no overall significant differences among the fertilization treatments (Table 3.4). The average was 297 mg Ca, ranging from 246 to 286 mg per plant.

3.3.2.4.2 Analysis of Effects of the Mature Compost Medium

There were no statistical differences among the regimes in the mature compost medium (Table 3.5). Plants accumulated an average of 218 mg Ca in the low proportion of compost, 203 mg in the medium proportion and 258 mg in the high proportion.

There were statistical differences among the fertilization treatments in the mature compost medium (Table 3.5). Plants grown with NO_3 addition accumulated 357 mg Ca. The treatment without K addition allowed plants to accumulate an average of 256 mg Ca. The treatment with K addition permitted the least amount of Ca accumulation with an average of 123 mg. Plants grown in the treatment without NO_3 addition accumulated an average of 170 mg Ca.

All the regimes with NO_3 addition increased Ca accumulation in the mature compost medium (Table 3.6). The increases were by 132% in the low proportion of compost, by 159% in the medium proportion and by 45.1% in the high proportion.

All the regimes with K addition decreased Ca accumulation in the mature compost medium (Table 3.6). The decreases were by 44.7% in the low proportion of compost, by 35.7% in the medium proportion and by 61.2% in the high proportion.

3.3.2.4.3 Analysis of Effects of the Immature Compost Medium

There were significant differences among the regimes in the immature compost medium (Table 3.5). Plants in the high proportion of compost accumulated the highest amount of Ca, averaging 376 mg. Plants in the medium proportion accumulated the second highest amount of Ca, averaging 302 mg, and in the low proportion plants accumulated average 229 mg Ca per plant.

There were statistical differences among the fertilization treatments in the immature compost medium (Table 3.5). Plants grown in the treatment without NO_3 addition accumulated 402 mg Ca. Plants in the treatment with K addition accumulated an average of 370 mg Ca. Plants in the treatment without K addition accumulated an average of 290 mg Ca. Plants in the treatment with NO_3 addition accumulated the least amount of Ca, averaging 148 mg per plant.

In the immature compost medium, basically there were opposite results compared with the mature compost medium regarding the interactions.

All the regimes with NO_3 addition decreased Ca accumulation in the immature compost medium (Table 3.6). The addition of NO_3 decreased Ca accumulation by 53.7% in the low proportion of compost, by 37.1% in the medium proportion and by 81.9% in the high proportion.

In the immature compost medium, K addition decreased Ca accumulation by 30.1% in the low proportion of compost. However it increased Ca accumulation by 8.9% in the medium proportion and by 99.9% in the high proportion (Table 3.6).

3.3.2.5 Magnesium

3.3.2.5.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.4). Plants grown in the immature compost medium accumulated an average of 59 mg of Mg, whereas in the mature compost medium plants accumulated an average of 43 mg. On this basis the immature compost medium provided 37.2% more Mg than the mature compost medium.

There were differences among the regimes (Table 3.4). The high proportion of compost permitted the highest amount of Mg accumulation with an average of 66 mg. The medium proportion and low proportion of compost statistically provided the same amount of Mg, averaging 44 mg per plant.

There were no overall significant differences in Mg accumulation among the fertilization treatments (Table 3.4). The average was 51 mg Mg, ranging from 46 to 55 mg per plant.

3.3.2.5.2 Analysis of Effects of the Mature Compost Medium

No statistical differences existed among the regimes in the mature compost medium (Table 3.5). The average accumulation was 43 mg, ranging from 37 to 52 mg per plant.

There were statistical differences among the fertilization treatments in the mature compost medium (Table 3.5). The treatments with NO_3 or without K addition statistically provided the same amount of Mg to plants, averaging 60 mg of Mg. The other two treatments statistically provided the same amount of Mg, averaging 26 mg of Mg accumulated.

All the regimes with NO_3 addition increased Mg accumulation in the mature compost medium (Table 3.6). The increases were by 140% in the low proportion of compost, by 204% in the medium proportion and by 56.3% in the high proportion.

All the regimes with K addition decreased Mg accumulation in the mature compost medium (Table 3.6). The decreases were by 45.3% in the low proportion of compost, by 39.5% in the medium proportion and by 67.2% in the high proportion.

3.3.2.5.3 Analysis of Effects of the Immature Compost Medium

There were statistical differences among the regimes in the immature compost medium (Table 3.5). Plants grown in the high proportion of compost accumulated the highest amount of Mg, averaging 79 mg. Plants grown in the other two regimes accumulated an average of 48 mg Mg per plant.

There were statistical differences among the fertilization treatments in the immature compost medium (Table 3.5). The treatments without NO_3 or with K addition statistically provided the same amount of Mg, averaging 77 mg. Plants grown in the treatment without K addition accumulated an average of 56 mg of Mg. The treatment with NO_3 addition provided an average of 26 mg of Mg.

In the immature compost medium, there were basically opposite results compared with the mature compost medium in the interactions among the regimes.

All the regimes with NO_3 addition decreased Mg accumulation in the immature compost medium (Table 3.6). The decreases were by 56.5% in the low proportion of compost, by 37.8% in the medium proportion and by 83.3% in the high proportion.

In the immature compost medium, K addition decreased Mg accumulation by 27.2% in the low proportion of compost. However it increased Mg accumulation by 10.6% in the medium proportion and by 113% in the high proportion (Table 3.6).

3.3.2.6 Total Leaf Nutrient Accumulations vs. Total Plant Dry Weight

Figures 3.8 to 3.11 present the relationship between each of single nutrient accumulation by tomato leaves and the total plant dry weight. The correlation between total N accumulation in plant leaves and total plant dry weight was in the linear form. All other correlation followed the trends expressed in the form of natural log regression.

There was a very high linear regression coefficient of 0.82 between total N accumulation by plant leaves and total dry weight. The relationship between the total P accumulation and the total dry weight was expressed by the regression coefficient of 0.76. The relationship between the total K accumulation and the total dry weight was described by the regression coefficient of 0.12. The relationship between the total Ca accumulation and the total dry weight was determined by the regression coefficient of 0.78, and the relationship between the total Mg accumulation and the total dry weight was determined by the regression coefficient of 0.74.

Each plant nutrient played a very important role in the plant dry weight gain, except that the relationship between K accumulation and total dry weight was not clear.

3.3.3 Effects of Immature Compost on Soil Nutrient Residual Availability

Tables 3.7, 3.8 and 3.9 present the entire picture of soil nutrient residual availability (the amount of nutrients remaining in the soil medium after harvest of the plants) affected by different compost media. Five soil nutrient elements were measured, including N, P, K, Ca, and Mg.

3.3.3.1 Nitrogen

3.3.3.1.1 Analysis of Overall Effects of the Two Compost Media

There was no significant difference between the mature and immature compost media (Table 3.7). There was an average of 40 mg/kg residual available N apiece.

There were no overall significant differences among the regimes (Table 3.7), the average residual available N was 40 mg/kg, ranging from 36 to 44 mg/kg.

There were differences among the fertilization treatments (Table 3.7). The treatment without NO_3 addition had the highest amount of residual available N, averaging 49 mg/kg. The treatments with K or without K addition statistically had the same amount of residual available N, averaging 40 mg/kg. The treatment with NO_3 addition had the least amount of residual available N, averaging 30mg/kg.

3.3.3.1.2 Analysis of Effects of the Mature Compost Medium

There were no statistical differences in residual N among the regimes in the mature compost medium (Table 3.8), averaging 40 mg/kg and ranging from 39 to 42 mg/kg.

There were no statistical differences among the fertilization treatments in the mature compost medium (Table 3.8). The average of residual available N was 40 mg/kg, ranging from 31 to 49 mg/kg.

All the regimes with NO_3 addition decreased soil N residual availability in the mature compost medium (Table 3.9). Compared with the non-fertilizer treatments, the decreases were by 6.9% in the low proportion of compost, by 33.2% in the medium proportion and by 39.6% in the high proportion. The more compost was used, the higher the decrease rate would be.

In the mature compost medium, K addition decreased soil residual N availability by 6.1% in the low proportion of compost. However it increased soil N residual availability by 101% in the medium proportion and by 104% in the high proportion (Table 3.9).

3.3.3.1.3 Analysis of Effects of the Immature Compost Medium

There were no statistical differences regarding residual N availability among the regimes in the immature compost medium (Table 3.8), the average was 40 mg/kg with a range of 33 and 45 mg/kg.

There were statistical differences among the fertilization treatments in the immature compost medium (Table 3.8). The treatment without NO_3 addition had the highest amount of residual available N, averaging 51 mg/kg. The treatment with NO_3 addition had the least amount of residual available N, averaging 28 mg/kg. The treatments with K or without K addition statistically had the same amount of residual available N, averaging 40 mg/kg.

All the regimes with NO_3 addition decreased soil N residual availability in the immature compost medium (Table 3.9). The decreases were by 37.3% in the low proportion of compost, by 57.3% in the medium proportion and by 45.0% in the high proportion.

In the immature compost medium, K addition increased soil N residual availability by 14.2% in the low proportion of compost and by 5.5% in the medium proportion. However, it decreased soil N residual availability by 27.1% in the high proportion (Table 3.9).

3.3.3.2 Phosphorus

3.3.3.2.1 Analysis of Overall Effects of the Two Compost Media

There was no significant difference between the mature and immature compost media (Table 3.7). They had averages of 28 ppm residual available P apiece.

There were significant differences among the regimes (Table 3.7). The high proportion of compost had the highest amount of residual available P, averaging 35mg/kg. The medium proportion had the second highest amount of residual available P, averaging 27mg/kg. The low proportion had the least amount of residual available P, averaging 21mg/kg.

There were significant differences among the fertilization treatments (Table 3.7). The treatment without K addition had the highest amount of residual available P, averaging 40 mg/kg. The treatment with K addition had the second highest amount of residual available P, averaging 29 mg/kg. The treatment without NO_3 addition had the third highest amount of residual available P, averaging 23 mg/kg. The treatment with NO_3 addition had the least amount of residual available P, averaging 18 mg/kg.

3.3.3.2.2 Analysis of Effects of the Mature Compost Medium

There were differences among the regimes in the mature compost medium (Table 3.8). The low proportion and medium proportion of compost statistically had the same amount of residual available P, averaging 25 mg/kg. The high proportion had an average of 33 mg/kg.

There were differences among the fertilization treatments in the mature compost medium (Table 3.8). The treatment without K addition had the highest amount of residual available P, averaging 40 mg/kg. The treatments with NO_3 or with K addition statistically had the same lowest amount of residual available P, averaging 20 mg/kg. The treatment without NO_3 addition had an average of 29 mg/kg of residual available P.

In the mature compost medium, the NO_3 addition increased soil P residual availability by 1.7% in the low proportion of compost and by 68.7% in the medium proportion. However, it decreased soil P residual availability dramatically by 72.4% in the high proportion (Table 3.9).

All the regimes with K addition decreased soil P residual availability in the mature compost medium (Table 3.9). The decreases were by 51.8% in the low proportion of compost, by 44.1% in the medium proportion and by 41.1% in the high proportion.

3.3.3.2.3 Analysis of Effects of the Immature Compost Medium

There were significant differences among the regimes in the immature compost medium (Table 3.8). The high proportion of compost had the highest amount of residual available P, averaging 37 mg/kg. The medium proportion had the second highest amount of soil residual available P, averaging 29 mg/kg. The low proportion had the least amount of residual available P, averaging 17 mg/kg.

There were differences among the fertilization treatments in the immature compost medium (Table 3.8). The treatment without K addition had the highest amount of residual available P, averaging 40 mg/kg. The treatment with K addition had the second highest amount of residual available P, averaging 37 mg/kg. The treatments with NO_3 and without NO_3 addition had same amount of residual available P, averaging 17 mg/kg.

In the immature compost medium, the NO_3 addition decreased soil P residual availability by 4.6% in the low proportion of compost and by 2.5% in the high proportion. However it increased soil P residual availability by 12.9% in the medium proportion (Table 3.9).

In the immature compost medium, the K addition increased soil P residual availability by 10.4% in the low proportion of compost. However it decreased soil P residual availability by 7.1% in the medium proportion and by 15.0% in the high proportion (Table 3.9).

3.3.3.3 Potassium

3.3.3.3.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature compost media (Table 3.7). The mature compost medium had an average of 226 mg/kg of residual available K, and the immature compost medium had an average of 85 mg/kg.

There were overall differences among the regimes (Table 3.7). The low proportion of compost had the highest amount of residual available K, averaging 227 mg/kg. The high proportion and medium proportion of compost statistically had the same amount of residual available K, averaging 120 mg/kg.

There were significant differences among the fertilization treatments (Table 3.7). The treatment with NO_3 addition had the highest amount of residual available K, averaging 240 mg/kg. The treatment without NO_3 addition had the second highest amount of residual available K, averaging 191 mg/kg. The treatments with K or without K addition had an average of 96 mg/kg apiece.

3.3.3.3.2 Analysis of Effects of the Mature Compost Medium

There were differences among the regimes in the mature compost medium (Table 3.8). The medium proportion and high proportion of compost statistically had the same amount of residual available K, averaging 162 mg/kg. The low proportion had an average of 353 mg/kg.

There were differences among the fertilization treatments in the mature compost medium (Table 3.8). The treatment with NO_3 and without NO_3 addition statistically had the same highest amount of residual available K, averaging 299 mg/kg. The treatments with K and without K additions had an average of 152 mg/kg residual available K apiece.

In the mature compost medium, the NO_3 addition decreased soil K residual availability by 10.4% in the low proportion of compost and by 5.6% in the high proportion. However, it increased soil K residual availability by 35.7% in the medium proportion (Table 3.9).

In the mature compost medium, the K addition increased soil K residual availability by 17.8% in the medium proportion of compost and by 79.7% in the high proportion.

However, it decreased soil K residual availability by 23.2% in the low proportion (Table 3.9).

3.3.3.3.3 Analysis of Effects of the Immature Compost Medium

There were differences among the regimes in the immature compost medium (Table 3.8). The low proportion and high proportion of compost statistically had the same amount of residual available K, averaging 100 mg/kg. The medium proportion had an average of 57 mg/kg.

There were differences among the fertilization treatments in the immature compost medium (Table 3.8). The treatment with NO_3 addition had the highest amount of residual available K, averaging 181 mg/kg. The treatment without NO_3 addition had the second highest amount of residual available K, averaging 85 mg/kg. The treatment without K addition had the least amount of residual available K, averaging 26 mg/kg. The treatment with K addition had an average of 50 mg/kg.

All the regimes with NO_3 addition increased soil K residual availability in the immature compost medium (Table 3.9). The increases were by 381% in the low proportion of compost, by 28.2% in the medium proportion and by 47.0% in the high proportion.

All the regimes with K addition increased soil K residual availability in the immature compost medium (Table 3.9). The increases were by 112% in the low proportion of compost, 179% in the medium proportion and 40.9% in the high proportion.

3.3.3.4 Calcium

3.3.3.4.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference in Ca residual availability between the mature and immature compost media (Table 3.7). The immature compost medium had an average of 241 mg/kg of residual available Ca, and the mature compost medium had an average of 212 mg/kg.

There were significant differences among the regimes (Table 3.7). The high proportion of compost had the highest amount of residual available Ca, averaging 267 mg/kg. The medium proportion had the second highest amount of residual available Ca, averaging 230 mg/kg. The low proportion had the least amount of residual available Ca, averaging 181 mg/kg.

There were significant differences in Ca residual availability among the fertilization treatments (Table 3.7). The average residual available Ca was 282 mg/kg in the treatment without K addition, 243 mg/kg in the treatment with K addition, 200 mg/kg in the treatment without NO_3 addition, and 180 mg/kg in the treatment with NO_3 addition.

3.3.3.4.2 Analysis of Effects of the Mature Compost Medium

There were significant differences in Ca residual availability among the regimes in the mature compost medium (Table 3.8). The high proportion of compost had the highest amount of residual available Ca, averaging 239 mg/kg. The medium proportion had an average of 212 mg/kg of residual available Ca. The low proportion had the least amount of residual available Ca, averaging 185 mg/kg.

There were differences among the fertilization treatments in the mature compost medium (Table 3.8). The treatments with NO_3, without NO_3 and with K addition statistically had the same amount of residual available Ca, averaging 196 mg/kg. The treatment without K addition averaged 261 mg/kg.

In the mature compost medium, the addition increased soil Ca residual availability by 4.8% in the low proportion of compost and by 60.3% in the medium proportion. However, it decreased Ca residual availability by 46.4% in the high proportion (Table 3.9).

All the regimes with K addition decreased soil Ca residual availability in the mature compost medium (Table 3.9). The decreases were by 25.6% in the low proportion of compost, by 23.0% in the medium proportion and by 33.1% in the high proportion.

3.3.3.4.3 Analysis of Effects of the Immature Compost Medium

There were significant differences in Ca residual availability among the regimes in the immature compost medium (Table 3.8). The high proportion of compost had the highest amount of residual available Ca, averaging 296 mg/kg. The medium proportion had an average of 248 mg/kg. The low proportion had an average of 177 mg/kg.

There were differences in Ca residual availability among the fertilization treatments in the immature compost medium (Table 3.8). The treatments with K or without K addition statistically had the same highest amount of residual available Ca, averaging 301 mg/kg. The treatment with NO_3 addition had the least amount of residual available Ca, averaging 168 mg/kg. The treatment without NO_3 addition had an average of 193 mg/kg.

In the immature compost medium, the NO_3 addition decreased soil Ca residual availability by 10.9% in the low proportion of compost and by 26.6% in the high proportion. However, it increased soil Ca residual availability by 9.7% in the medium proportion (Table 3.9).

In the immature compost medium, the K addition slightly increased soil Ca residual availability by 0.2% in the low proportion of compost. However, it slightly decreased soil Ca residual availability by 0.1% in the medium proportion and by 3.7% in the high proportion (Table 3.9).

3.3.3.5 Magnesium

3.3.3.5.1 Analysis of Overall Effects of the Two Compost Media

There was no significant difference in Mg residual availability between the mature and immature compost media (Table 3.7). The immature compost medium had an average of 18.2 mg/kg residual available Mg, and the mature compost medium had an average of 17.5 mg/kg.

There were differences in Mg residual availability among the regimes (Table 3.7). The high proportion and medium proportion of compost statistically had the same amount of residual available Mg, averaging 18.7 mg/kg. The low proportion of compost averaged 16.0 mg/kg.

There were some differences among the fertilization treatments (Table 3.7). The treatment with K addition had the highest amount of residual available Mg, averaging 21.4 mg/kg. All other treatments statistically had the same amount of residual available Mg, averaging 16.7 mg/kg.

3.3.3.5.2 Analysis of Effects of the Mature Compost Medium

There were no statistical differences in Mg residual availability among the regimes in the mature compost medium (Table 3.8), averaging 17 mg/kg.

There were differences among the fertilization treatments in the mature compost medium (Table 3.8). The treatment without NO_3 addition had the highest amount of available residual Mg, averaging 19 mg/kg. The treatments with or without K addition statistically had the same amount of soil residual Mg, averaging 18 mg/kg. The treatment with NO_3 addition had an average of 16 mg/kg.

All the regimes with NO_3 addition decreased soil Mg residual availability in the mature compost medium (Table 3.9). The decreases were by 23.4% in the low proportion of compost, by 4.2% in the medium proportion and by 21.7% in the high proportion.

In the mature compost medium, the K addition decreased soil Mg residual availability by 17.1% in the low proportion of compost and by 3.3% in the medium proportion. However, it increased soil Mg residual availability by 59.0% in the high proportion (Table 3.9).

3.3.3.5.3 Analysis of Effects of the Immature Compost Medium

There were differences in Mg residual availability among the regimes in the immature compost medium (Table 3.8). The high and medium proportion of compost had the same amount of residual available Mg, averaging 20 mg/kg apiece. The low proportion had an average of 15 mg/kg.

There were differences in Mg residual availability among the fertilization treatments in the immature compost medium (Table 3.8). The treatment with K addition had the highest amount of residual available Mg, averaging 25 mg/kg. The other three treatments statistically had the same amount of residual available Mg, averaging 15 mg/kg apiece in the treatments with and without NO_3 addition, and 18 mg/kg in the treatment without K addition.

In the immature compost medium, the NO_3 addition decreased soil Mg residual availability by 6.0% in the medium proportion of compost and by 2.1% in the high proportion. However, it increased soil Mg residual availability by 27.4% in the low proportion (Table 3.9).

All the regimes with K addition increased soil Mg residual availability in the immature compost medium (Table 3.9). The increases were by 5.2% in the low proportion of compost, by 1.9% in the medium proportion and by 156% in the high proportion.

The highest increases of soil Mg residual availability were in the treatment with K addition in the high portion of compost.

3.4 Discussion

3.4.1 Effects of Immature Composts on Plant Growth

Overall, the immature compost medium showed better results than the mature compost medium regarding plant growth. Plants grown in the immature compost medium produced more flowers and fruits than those grown in the mature compost medium. The immature compost medium also produced a larger total number, and fresh and dry mass of leaves. Plants grown in the immature compost medium also had larger stem mass. As a consequence of more numerous leaves and larger leaf mass and larger stem mass, the total mass of plants grown in immature compost medium was larger than that in the mature compost medium. They statistically produced the same results for the fruit fresh or dry weights in either mature or immature compost medium. The mature compost medium gave better results in plant height than the immature compost medium.

This improvement of plant growth in the immature compost medium was attributed to the fact that it was rich in ammonium, which acted as a fertilizer.

In general, regimes, different volumetric mixes of compost and soil, did not differ significantly in promoting plant growth. Plant heights, numbers of flower, fruit weights, numbers of leaf, stem weights, and total mass did not differ statistically among the regimes. The occasionally better results from the higher proportion of compost used, usually not significant, might be attributed to the nutrients delivered by the composts. The interaction of composts and regimes were important, however.

For example, with the immature compost, the regime of medium proportion of compost usually gave better plant growth than the low or high proportion of compost. This response is likely again due to the delivery of N from the immature compost. The low proportion of compost appeared to give too little N for adequate plant nutrition, whereas the high addition likely gave an initially excessive amount of ammonium that was phytotoxic to the young plants. When the mature compost was used, the regime of high proportion of compost generally yielded better results than the medium and low proportion of compost. This enhancement in growth could be attributed to the nutrients contained in the compost—the more compost was used, the more nutrients were provided.

The effects of fertilizer treatmnt had importance in their interactions with the different composts in the media. Some growth indices, such as leaf dry weight, stem dry weight and total dry weight were adversely affected by the fertilizer treatment with NO_3

addition. These effects appeared to be due to the interaction of NO_3 with the immature compost and N-rich condition imparted by the NH4 in the immature compost. NO3 addition did not have suppressive effects on plant growth in the mature compost medium with the consistency that it did in the immature compost medium.

Fertilization with NO_3 in the mature compost medium generated favorable plant growth responses. The treatment with calcium nitrate addition commonly gave the best results. This response is likely due to the fact that the mature compost was depleted or low in readily available N. The addition of calcium nitrate gave the plants necessary N for their growth.

The addition of K generally suppressed growth in the mature media. This suppression is likely due to an imbalance between N and K nutrition or because of salinity introduced by the K salts. There was also an indication that K suppressed accumulation of Ca and Mg in the leaves. The addition of K generally improved plant growth in the immature compost medium, which had high content of ammonium. Additional K nutrition has been shown to be important in lessening ammonium toxicity to plants, and plants receiving ammonium nutrition require higher levels of K nutrition than those receiving nitrate nutrition (Barker and Lachman, 1986; Barker, 1976; Corey and Barker, 1989; Feng and Barker, 1992; Barker et al., 1967)

As noted in the previous chapter, relationships between various growth indices and total plant dry weight were correlated. Some of those parameters could be used to predict the tomato plant production without undertaking destructive harvest. Among the ten growth indices (except for plant height, fruit fresh weight, or fruit dry weight which did not correlate with total dry weight), seven growth indices were significantly correlated with total dry weight. The analysis showed that the numbers of flower, the numbers of leaf, the leaf fresh and dry weights, and stem fresh and dry weights carried regression coefficients larger than 0.85. Growth indices such as numbers of flower and numbers of leaf can be used to predict tomato plant production well without destructive harvests.

3.4.2 Effects of Immature Composts on Leaf Nutrient Accumulations

Generally speaking, the immature compost medium generated better results than the mature compost medium on leaf nutrient accumulations. Accumulations of N, P, Ca, and Mg in tomato leaves in the immature compost medium were higher than in leaves of plants grown in the mature compost medium. However, accumulation of K in the immature compost medium was lower than in the media with mature compost. Commonly, high ammonium concentrations in media depress accumulations of catitonic (K, Ca, Mg) nutrients and increase accumulation of anionic nutrients (N, P) (Barker, 1967; Barker et al., 1966; Maynard and Barker, 1969).

Accumulations of N, P, Ca, and Mg in plant leaves were highly correlated with total plant growth (total dry weight). This trend was more apparent in the immature compost medium than in the mature compost medium. Accumulation of these nutrients appeared to be related to regimes and to modes of fertilzation and their interactions with the maturity of compost. Accumulations of N, P, Ca, and Mg rose as the proportions of immature compost in the media increased from the low to middle regime and sometimes to the upper regime, but regimes had no effects on accumulation of these nutrients in the mature compost medium. The effects appear to be a function of enhanced plant growth with the higher proportions of immature compost. Potassium accumulation was suppresed as proportions of immature compost increases, as K accumulation was likely suppressed by the higher supply of ammonium.

Nitrate additions increased accumulations of all nutrients in the mature compost medium but suppressed accumulation in the immature compost medium. These are related to the suppressive effects of calcium from the calcium nitrate on the base absorption but are more likely due to the suppressive effect that additional nitrate had on plant growth in the immature compost.

Accumulation of K was not correlated with total plant dry weight. However, the accumulation of K in the mature compost medium was much higher than that accumulated in the immature compost medium. This result is attributed also to the suppressive effect that ammonium had on K absorption in the immature media.

The analysis of leaf nutrient accumulations further suggested that adding nitrate was beneficial in promoting growth and nutrient accumulation in the mature compost medium and that adding K was beneficial in promoting growth and nutrient accumulation in the immature compost medium. These results are attributed to the response to additional N from calcium nitrate added to the mature media as the immature media were N rich from ammonium. In the immature meida, the addition of K was beneficial for growth of plants receiving nutrition largely from ammonium sources. Plants receiving a major portion of their nutrition from ammonium require enhanced K nutrition relative to plants receiving their nutrition mainly from nitrate (Barker, 1967).

3.4.3 Effects of Immature Compost on Soil Residual Nutrient Availability

The residual available nutrients, retained in the media at the end of the experiment were related to the interactions of treatments and the effects of these treatments on plant growth and nutrient absorption. In the mature compost medium, the regime of high proportion of compost had higher content of residual available N, P, Ca, and Mg than other two regimes. But the regime of low proportion of compost had highest amount of soil residual available K. These differences in nutrient residual availability did not appear to be related to toal nutrient removal from the media. Perhaps, the higher proportion of soil allowed for retention of K by exchange or fixation in the mineral soil particles. The higher amount of other four nutrients might be attributed to the higher amount of those nutrients being provided by the higher proportion of compost.

The treatment with nitrate addition to mature compost generally increased the accumulations of N, P, Ca, and Mg and reduced soil residual available quantity of those nutrients. The treatment with nitrate addition also greatly increased the accumulation of K in plant leaves. However, the treatment did not affect soil residual available K. Perhaps the treatment with calcium nitrate stimulated K accumulation but also allowed for release of K into solution by cation exchange and resulted in more total available K to balance K absorption.

In the immature compost medium, the regime of high proportion of compost generally had higher residual available all nutrients except K than the other regimes, particularly more than the regime with a low proportion of compost. The higher residual availability of nutrients might be attributed to the higher amount of those nutrients provided by the higher proportion of compost. The lack of effect on K residual availability may be due to depletion of K from the media as the supply of ammonium increased with increases in proportions of compost and increases the demand for K from the media.

The treatment with NO3 addition had little effects on nutrient residual availability in the media at the end of the experiment. Additions of K had little effect on residual availability of nutrients in the media, even on K.

The maturity of compost was an important factor in assessing the effects of composts on tomato growth. Mature compost had the advantage over immature composts in that the mature compost did not have the hostile effects of hight amounts of ammonium. Plants growing in media based on mature compost beneifited from fertilization with nitrate, as these media are characteristically low in N. Plants grown in immature compost did not benefit from additional N fertilization, as the ammonium supply was sufficient and further applications of N were deleterious to growth. Immature composts were improved in their capacities to increase plant growth if additional K fertilization was provided. The capacity of plants to assimilate ammonium is enhanced if K supply is not limiting. The beneficial effects of regimes were due to the elevated supply of plant nutrients as the proportion of composts in the media increased. The effects on accumulation of nutrients in plants and nutrient residual availability in media were complex and were related to factors such as total plant growth and interactions of nutrients with one another with respect to availability for absorption by plants. The principal conclusion from this experiment is that plants growing in mature compost benefit from N fertilization and that plants in ammonium-rich immature compost benefit from K fertilization.

Table 3.1 Comparison of Overall Averages of Growth Indices for 2nd Experiment

Index	Variables								
	Composts		Regimes			Fertilization			
	Mature	Immature	Low	Medium	High	NO_3	No NO_3	K	No K
Height (cm)	94a	89b	90a	93a	91a	88a	91a	93a	93a
No. of Flower	45b	62a	50a	57a	54a	51a	57a	54a	52a
No. of Fruit	4.0b	5.8a	3.8b	5.3a	5.8a	5.5a	5.1a	5.3a	3.9a
Fruit FW (g)	89a	89a	73a	94a	100a	87a	105a	93a	70a
Fruit DW (g)	5.1a	5.4a	4.3a	5.4a	6.0a	4.9a	6.0a	5.7a	4.3a
No. of Leaf	35b	46a	39a	41a	41a	40a	42a	39a	40a
Leaf FW (g)	130b	199a	143b	178a	172a	157a	180a	158a	164a
Leaf DW (g)	17.2b	25.9a	19.4b	22.9a	22.5ab	20.8ab	24.1a	19.8b	21.6ab
Stem FW (g)	106b	129a	110a	126a	116a	106a	124a	119a	121a
Stem DW (g)	15.6b	17.9a	16.6a	17.6a	16.2a	14.8b	17.8a	16.8ab	17.7a
Total DW (g)	38b	49a	40a	46a	45a	41b	48a	42ab	44ab

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).
FW= Fresh Weight; DW= Dry Weight.

Table 3.2 Comparison of Growth Index Averages for Mature and Immature Compost in 2nd Experiment

Index	Mature Compost							Immature Compost						
	Regimes			Fertilization				Regimes			Fertilization			
	Low	Med.	High	NO_3	No NO_3	K	No K	Low	Med.	High	NO_3	No NO_3	K	No K
Height (cm)	92b	93ab	98a	94a	94a	93a	96a	88ab	94a	84b	82b	88ab	93a	90ab
No. of Flower	46a	43a	45a	56a	43ab	37b	43ab	54b	70a	63ab	46b	71a	71a	61ab
No. of Fruit	3.2b	4.3ab	4.6a	6.6a	3.6b	3.2b	2.8b	4.3b	6.3ab	6.9a	4.3a	6.6a	6.8a	5.6a
Fruit FW (g)	60b	93ab	112a	86a	111a	97a	60a	85a	94a	87a	62a	125a	89a	80a
Fruit DW (g)	3.7b	5.2ab	6.4a	5.0a	5.9a	5.7a	3.9a	4.9a	5.6a	5.6a	3.9a	7.1a	5.8a	4.7a
No. of Leaf	37a	33a	36a	42a	35b	30b	34 b	42a	48a	47a	38b	50a	49a	46ab
Leaf FW (g)	126a	123a	142a	179a	133b	90c	117bc	161b	234a	203a	135b	227a	226a	210a
Leaf DW (g)	17a	16a	19a	24a	18b	11c	16bc	22b	30a	26ab	18b	30a	28a	28a
Stem FW (g)	105a	102a	112a	124a	109ab	88b	103ab	115b	151a	120b	88b	138a	153a	137a
Stem DW (g)	16a	15a	16a	16a	17a	13a	16a	17ab	20a	16b	12b	20a	21a	19a
Total DW (g)	37a	36a	41a	45a	41ab	30c	35bc	44b	56a	48ab	34b	57a	55a	51a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).
FW= Fresh Weight; DW= Dry Weight.

Table 3.3 2nd Experiment Growth Index Average for A: Mature Compost, B: Immature Compost

A: Mature Compost

Regime	Fertilizer	Height	Flower #	Fruit			Leaf			Stem		TDW
			#	#	FW	DW	#	FW	DW	FW	DW	
		cm			--------g-------			------------------	----g----	------------------		
L	NO3	89	69	5.3	56	3.3	46	193	26	132	20	49
	No	91	48	3.3	57	3.5	40	145	21	121	19	43
M	NO3	94	54	6.3	143	7.0	44	177	24	129	17	48
	No	94	41	4.3	61	4.0	29	117	16	97	15	35
H	NO3	99	45	8.3	139	7.6	38	167	22	112	16	45
	No	98	40	3.3	134	7.2	35	138	17	110	14	39
L	K	92	33	3.0	67	4.2	29	67	8	80	12	24
	No	95	36	1.3	60	3.9	33	97	13	86	14	31
M	K	90	43	4.0	98	5.3	28	98	12	87	13	31
	No	93	35	2.5	69	4.7	31	99	19	94	14	32
H	K	98	36	4.0	127	7.7	32	105	14	89	14	35
	No	100	59	3.0	50	3.0	41	157	21	136	21	45

Abbreviations: L= low proportion of compost; M= medium proportion of compost; H= high proportion of compost; FW= Fresh Weight; DW= Dry Weight, and TDW= Total Dry Weight.

Continued next page.

B: Immature Compost

Regime	Fertilizer	Index: Height	Flower	Fruit			Leaf			Stem		
			#	#	FW	DW	#	FW	DW	FW	DW	TDW
		cm			--------g-------			------------------------------g-------------------------				
L	NO3	87	49	4.8	70	4.1	41	140	18	102	14	37
	No	87	61	5.3	79	4.8	47	187	26	127	19	50
M	NO3	90	57	5.0	79	5.1	47	198	25	114	16	46
	No	89	76	8.5	181	9.9	48	224	30	138	20	60
H	NO3	69	30	3.3	37	2.6	27	67	10	48	7	19
	No	89	76	6.0	116	6.7	54	269	35	150	20	61
L	K	86	49	2.8	84	5.2	35	131	17	102	15	37
	No	92	56	4.5	109	5.7	46	184	26	130	20	52
M	K	103	79	6.8	70	4.7	50	274	33	190	24	62
	No	93	69	4.8	48	2.8	47	240	30	164	21	54
H	K	92	87	11.0	112	7.4	61	273	35	166	23	65
	No	87	59	7.5	82	5.6	45	204	26	117	16	48

Abbreviations: L= low proportion of compost; M= medium proportion of compost; H= high proportion of compost; FW= Fresh Weight; DW= Dry Weight, and TDW= Total Dry Weight.

Table 3.4 Overall Comparison of Leaf Nutrient Accumulations for 2nd Experiment

Element	Variables								
	Composts		Regimes			Fertilization			
(mg)	Mature	Immature	Low	Medium	High	NO_3	No NO_3	K	No K
N	367 b	805 a	526 a	622 a	611 a	553 a	609 a	570 a	614 a
P	45.9 b	78.1 a	51.2 b	67.1 a	67.8 a	45.4 b	56.6 b	73.4 a	72.7 a
K	342 a	215 b	263 a	310 a	263 a	314 a	280 a	242 a	278 a
Ca	227 b	302 a	223 b	253 b	317 a	253 a	286 a	246 a	273 a
Mg	42.6 b	58.9 a	39.7 b	46.9 b	65.6 a	45.7 a	52.4 a	49.7 a	55.0 a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 3.5 Comparison of Leaf Nutrient Accumulations for Mature and Immature Composts in 2nd Experiment

Elements	Mature Compost							Immature Compost						
	Regime			Fertilization				Regime			Fertilization			
(mg)	Low	Med.	High	NO_3	No NO_3	K	No K	Low	Med.	High	NO_3	No NO_3	K	No K
N	380a	351a	371a	607a	311bc	187c	365b	673b	892a	852ab	498b	907a	954a	862a
P	44a	45a	49a	51a	46a	36a	51a	58b	89a	87a	39c	68b	111a	94a
K	329a	323a	372a	524a	263b	235b	344b	196b	297a	153b	103b	296a	248a	213a
Ca	218a	203a	258a	357a	170bc	123c	256b	229c	302b	376a	148c	402a	370ab	290b
Mg	37a	39a	52a	65a	28b	23b	54a	42b	55b	79a	26c	77a	77a	56b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 3.6 2nd Experiment Leaf Nutrient Concentration (%)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg	Leaf DW
Mature	L	NO3	3.00	0.21	1.70	1.69	0.29	26 g
		No	1.73	0.22	1.56	0.92	0.15	21 g
	M	NO3	3.01	0.21	1.28	1.58	0.31	24 g
		No	1.75	0.28	2.43	0.90	0.15	16 g
	H	NO3	1.46	0.22	1.47	0.93	0.16	22 g
		No	1.71	0.37	2.45	1.16	0.21	17 g
	L	K	1.87	0.31	2.97	1.04	0.18	8 g
		No	1.76	0.39	2.42	1.19	0.21	13 g
	M	K	1.64	0.34	2.05	1.31	0.25	12 g
		No	1.61	0.37	1.91	1.00	0.18	19 g
	H	K	1.64	0.31	1.90	1.24	0.24	14 g
		No	3.04	0.27	2.01	2.00	0.45	21 g
Immature	L	NO3	2.97	0.22	0.73	0.89	0.16	18 g
		No	3.08	0.21	0.57	1.37	0.25	26 g
	M	NO3	2.62	0.21	1.65	0.71	0.12	25 g
		No	2.59	0.19	0.47	0.93	0.16	30 g
	H	NO3	2.98	0.26	0.57	1.06	0.19	10 g
		No	3.31	0.26	0.76	1.63	0.33	35 g
	L	K	3.20	0.31	0.70	0.96	0.18	17 g
		No	3.10	0.32	1.49	0.90	0.17	26 g
	M	K	3.39	0.39	1.24	1.17	0.22	33 g
		No	3.33	0.39	0.57	1.19	0.22	30 g
	H	K	3.39	0.43	0.60	1.06	0.23	35 g
		No	3.14	0.31	0.30	1.58	0.35	26 g

Abbreviations: L= low proportion of compost; M= medium proportion of compost; H= high proportion of compost; and DW= dry weight.

Table 3.7 2nd Experiment Leaf Nutrient Accumulations (mg)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg	Leaf DW
Mature	L	NO3	786	55	446	443	75	26 g
		No	357	46	325	191	31	21 g
	M	NO3	718	51	597	378	75	24 g
		No	276	45	201	146	25	16 g
	H	NO3	316	48	530	251	46	22 g
		No	298	46	262	173	29	17 g
	L	K	144	23	225	85	15	8 g
		No	232	51	322	153	27	13 g
	M	K	199	41	218	113	21	12 g
		No	212	44	276	176	34	19 g
	H	K	218	43	264	171	33	14 g
		No	652	57	433	439	100	24 g
Immature	L	NO3	547	41	133	165	29	18 g
		No	802	55	149	357	66	26 g
	M	NO3	659	52	120	177	31	25 g
		No	774	56	481	281	50	30 g
	H	NO3	290	25	57	103	19	10 g
		No	1145	91	259	267	113	35 g
	L	K	538	54	119	162	31	17 g
		No	803	84	382	232	43	26 g
	M	K	1125	130	411	391	74	33 g
		No	1009	118	175	359	67	30 g
	H	K	1198	150	214	557	125	35 g
		No	775	81	83	279	59	26 g

Abbreviations: L= low proportion of compost; M= medium proportion of compost; H = high proportion of compost; DW= dry weight.

Table 3.8 Comparison of Soil Residual Available Nutrient Contents for 2nd Experiment

Element	Variables								
	Composts		Regimes			Fertilization			
(mg/kg)	Mature	Immature	Low	Medium	High	NO3	No NO3	K	No K
N	40a	40a	36a	44a	40a	30b	49a	44ab	36ab
P	28a	28a	21c	27b	35a	18d	23c	29b	40a
K	226a	85b	227a	115b	124b	240a	191b	100c	91c
Ca	212b	241a	181c	230b	267a	180d	200c	243b	282a
Mg	18a	18a	16b	19a	19a	16b	17b	21a	18b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 3.9 Comparison of Soil Residual Available Nutrient Contents for Mature and Immature Composts in 2nd Experiment

	Mature Compost							Immature Compost						
Elements	Regime			Fertilization				Regime			Fertilization			
(mg/kg)	Low	Med.	High	NO_3	No NO_3	K	No K	Low	Med.	High	NO_3	No NO_3	K	No K
N	39a	42a	39a	33a	46a	49a	31a	33a	45a	41a	28b	51a	40ab	41ab
P	24b	26b	33a	19c	29b	22c	40a	17c	29b	37a	17c	17c	37b	40a
K	353a	174b	150b	300a	298a	150b	155b	102a	57b	97a	181a	85b	50bc	26c
Ca	185c	212b	239a	193b	206b	189b	261a	177c	248b	296a	168c	193b	298a	303a
Mg	17a	17a	18a	16b	19a	18ab	17ab	15b	20a	20a	15b	15b	25a	18b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 3.10 Soil Residual Available Nutrient Contents for 2nd Experiment (mg/kg)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg
Mature	L	NO3	30	18	411	183	15
		No	32	18	459	174	20
	M	NO3	43	25	260	236	14
		No	64	15	192	148	14
	H	NO3	25	15	229	159	18
		No	42	54	243	296	23
	L	K	45	20	236	163	15
		No	48	41	307	219	18
	M	K	44	23	132	203	20
		No	22	41	112	263	21
	H	K	58	23	83	200	19
		No	29	38	46	300	12
Immature	L	NO3	22	12	263	145	14
		No	35	13	55	163	11
	M	NO3	29	15	99	161	13
		No	69	13	77	147	13
	H	NO3	33	23	180	198	19
		No	59	24	122	270	19
	L	K	46	23	60	201	18
		No	40	21	28	200	17
	M	K	42	42	38	342	27
		No	40	45	14	343	26
	H	K	31	46	51	351	29
		No	42	54	36	365	11

Abbreviations: L= low proportion of compost; M= medium proportion of compost; H= high proportion of compost.

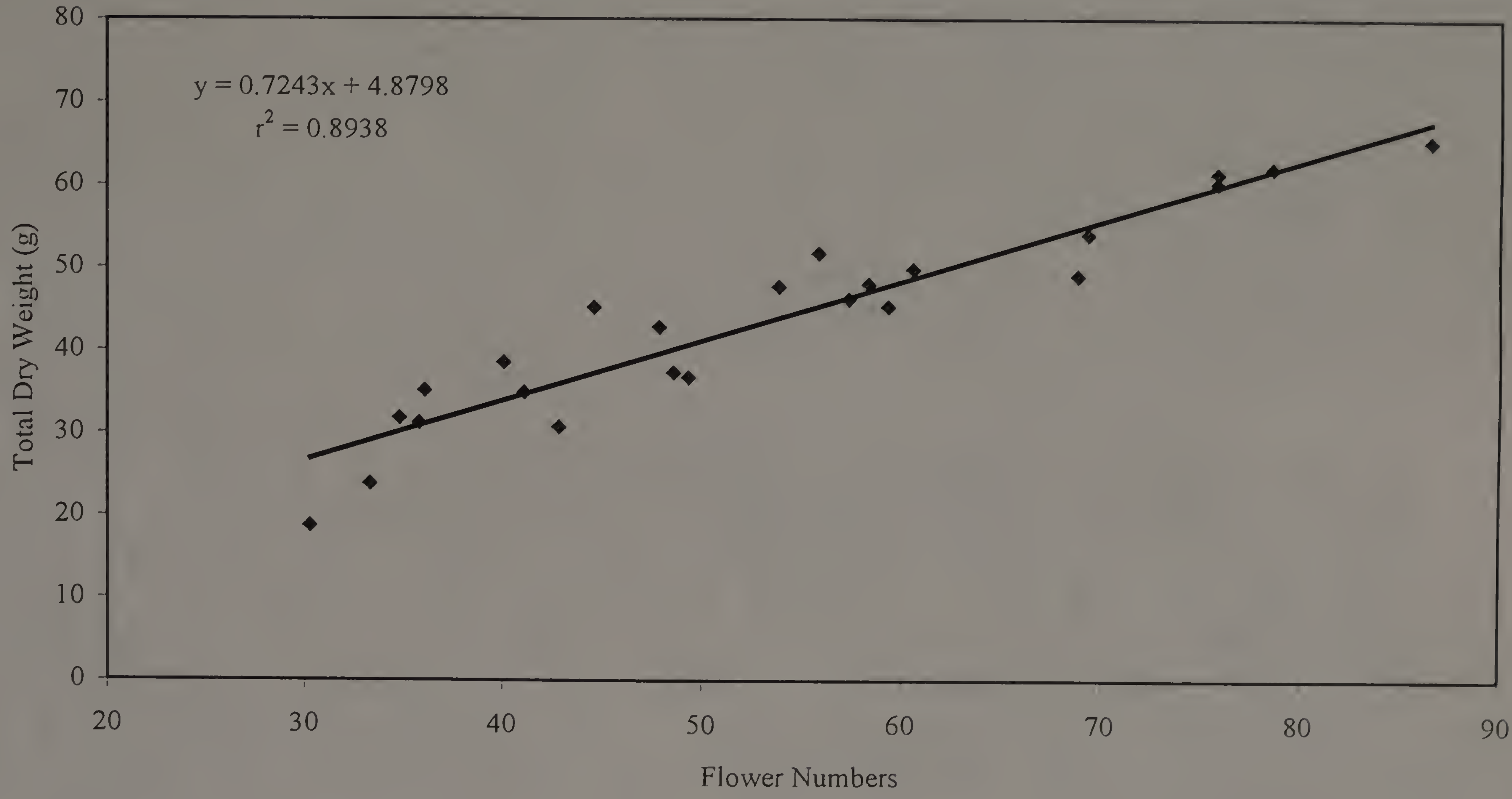


Figure 3.1. Relationship between Flower # and Total Dry Weight for 2nd Experiment

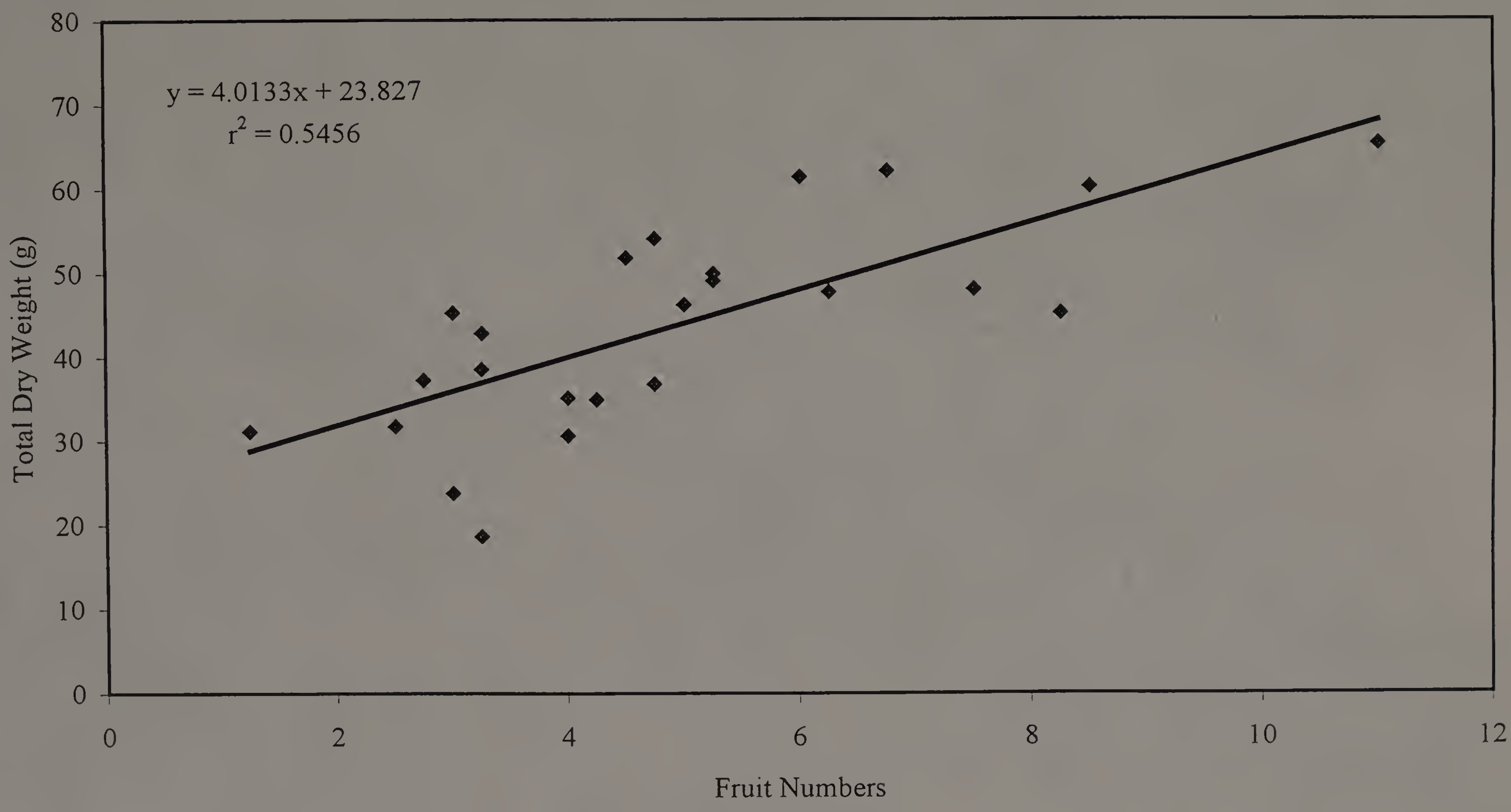


Figure 3.2. Relationship between Fruit # and Total Dry Weight for 2nd Experiment

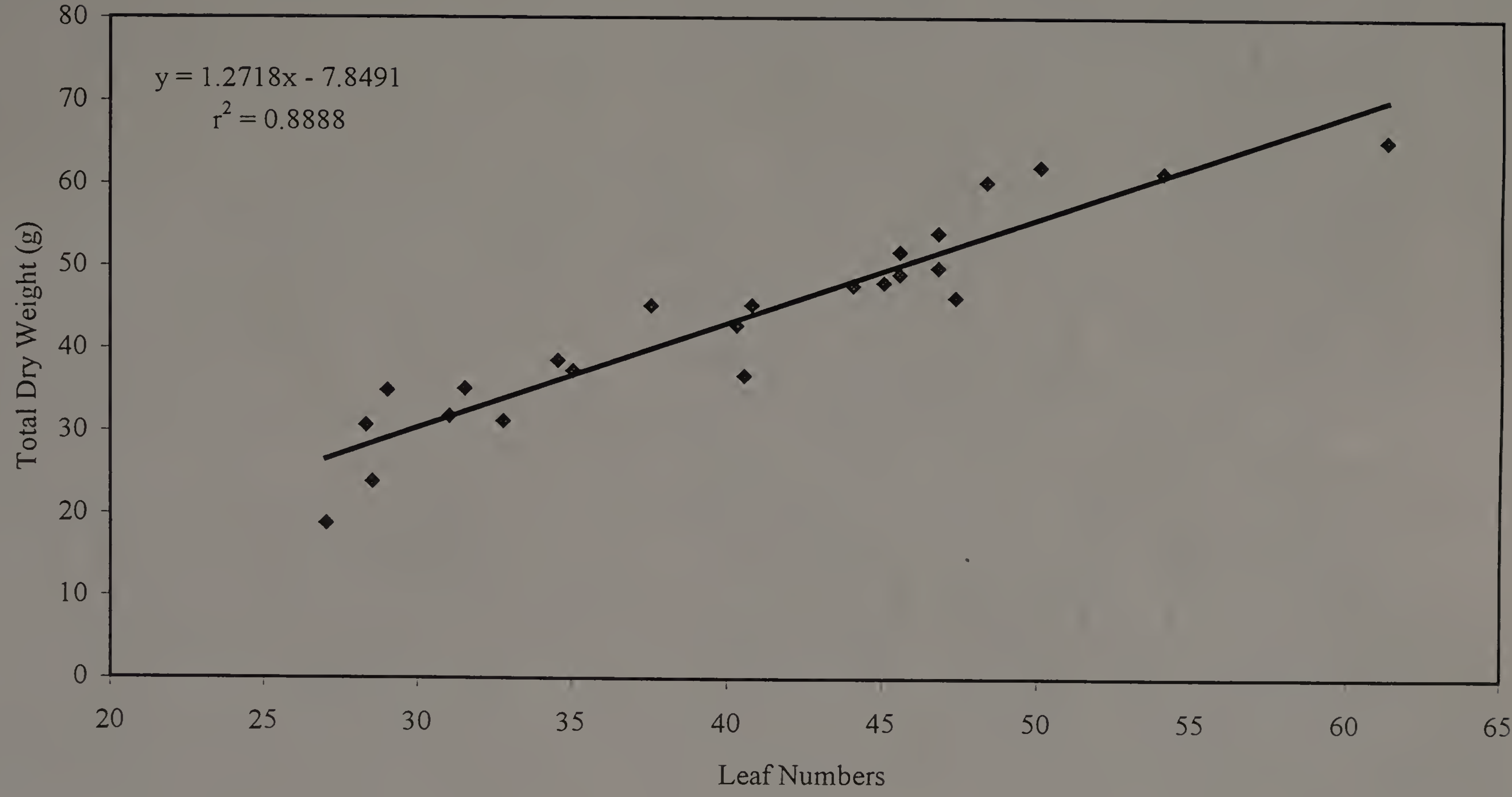


Figure 3.3. Relationship between Leaf # and Total Dry Weight for 2nd Experiment

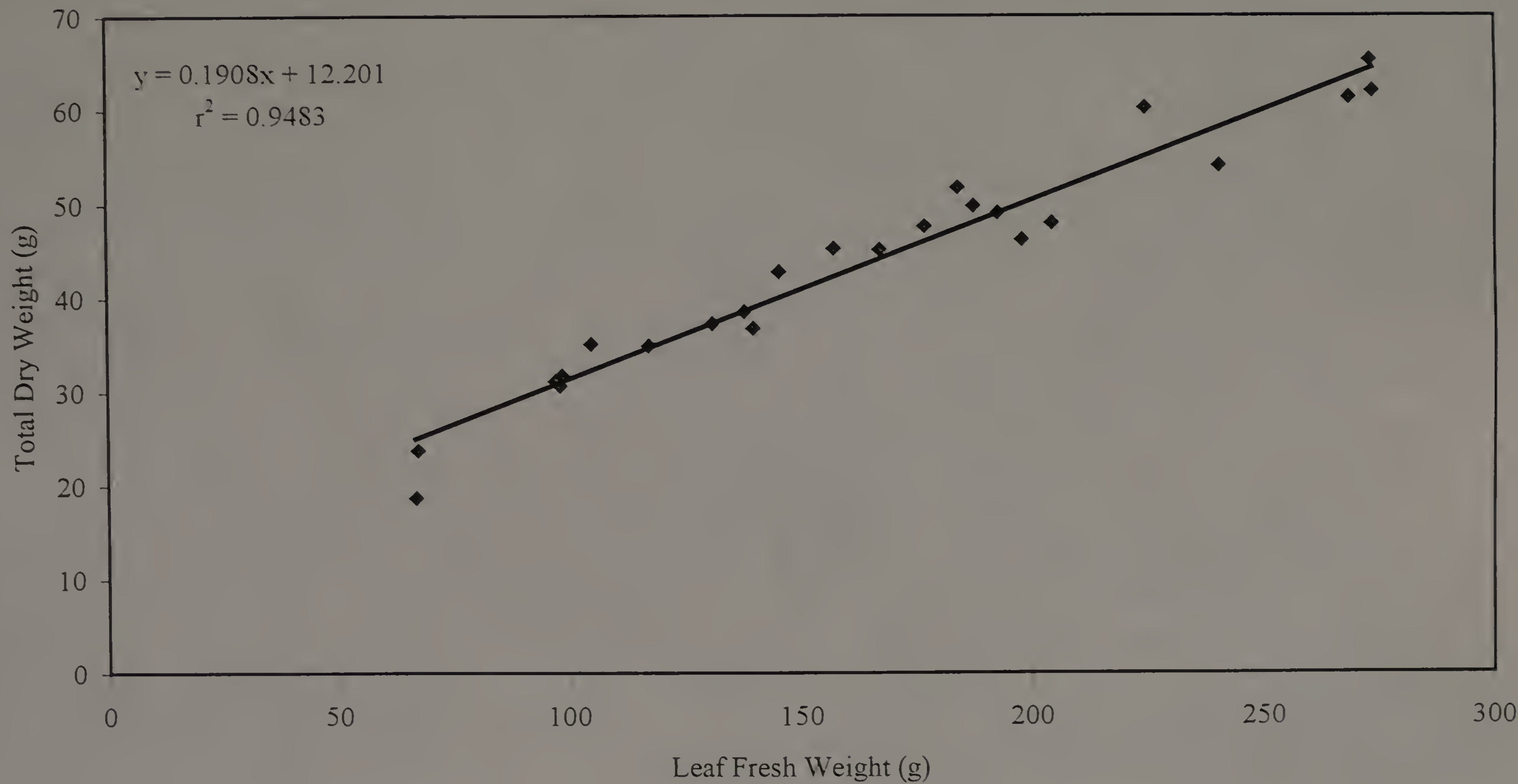


Figure 3.4. Relationship between Leaf Fresh Weight and Total Dry Weight for 2nd Experiment

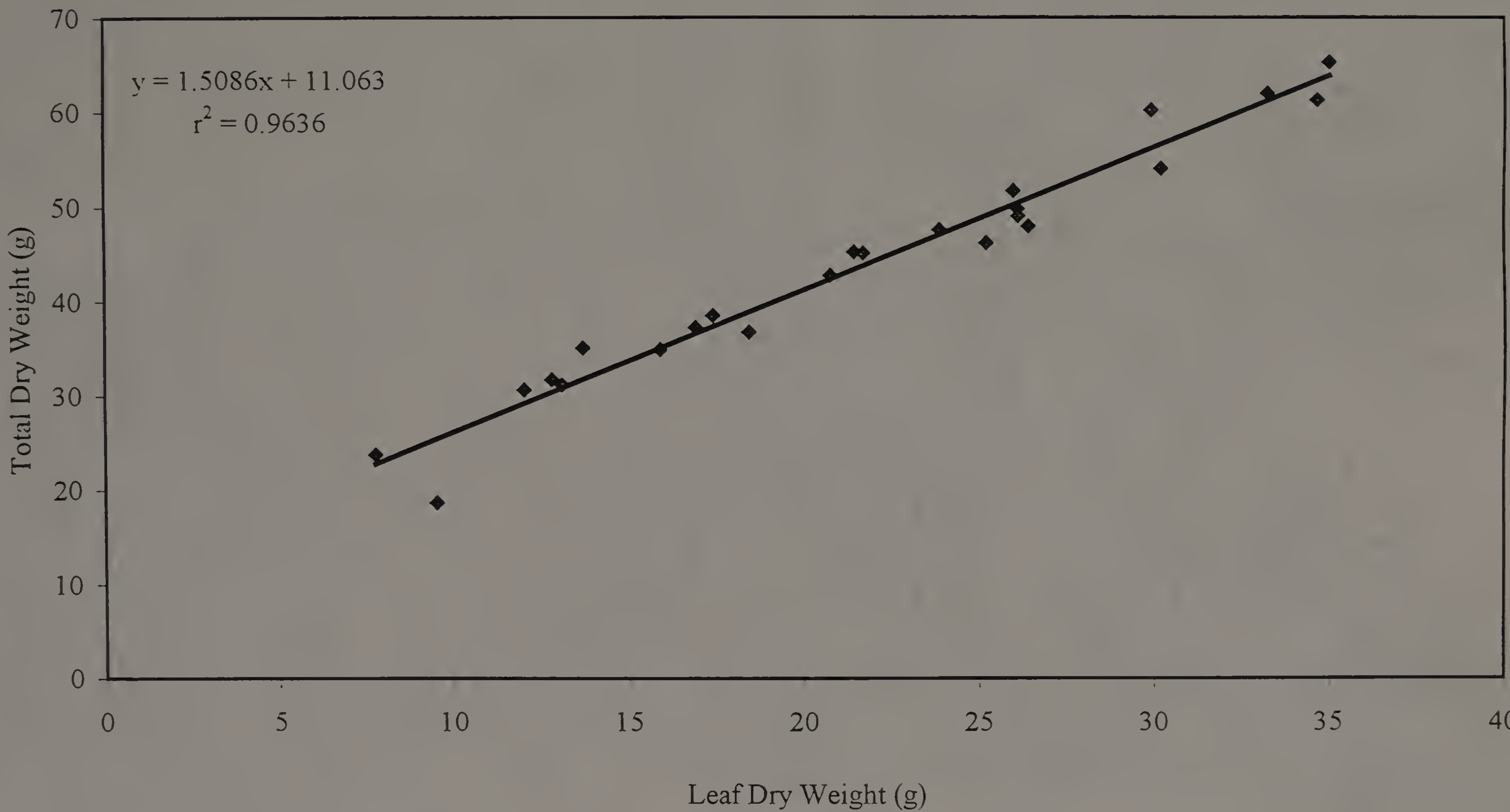


Figure 3.5. Relationship between Leaf Dry Weight and Total Dry Weight for 2nd Experiment

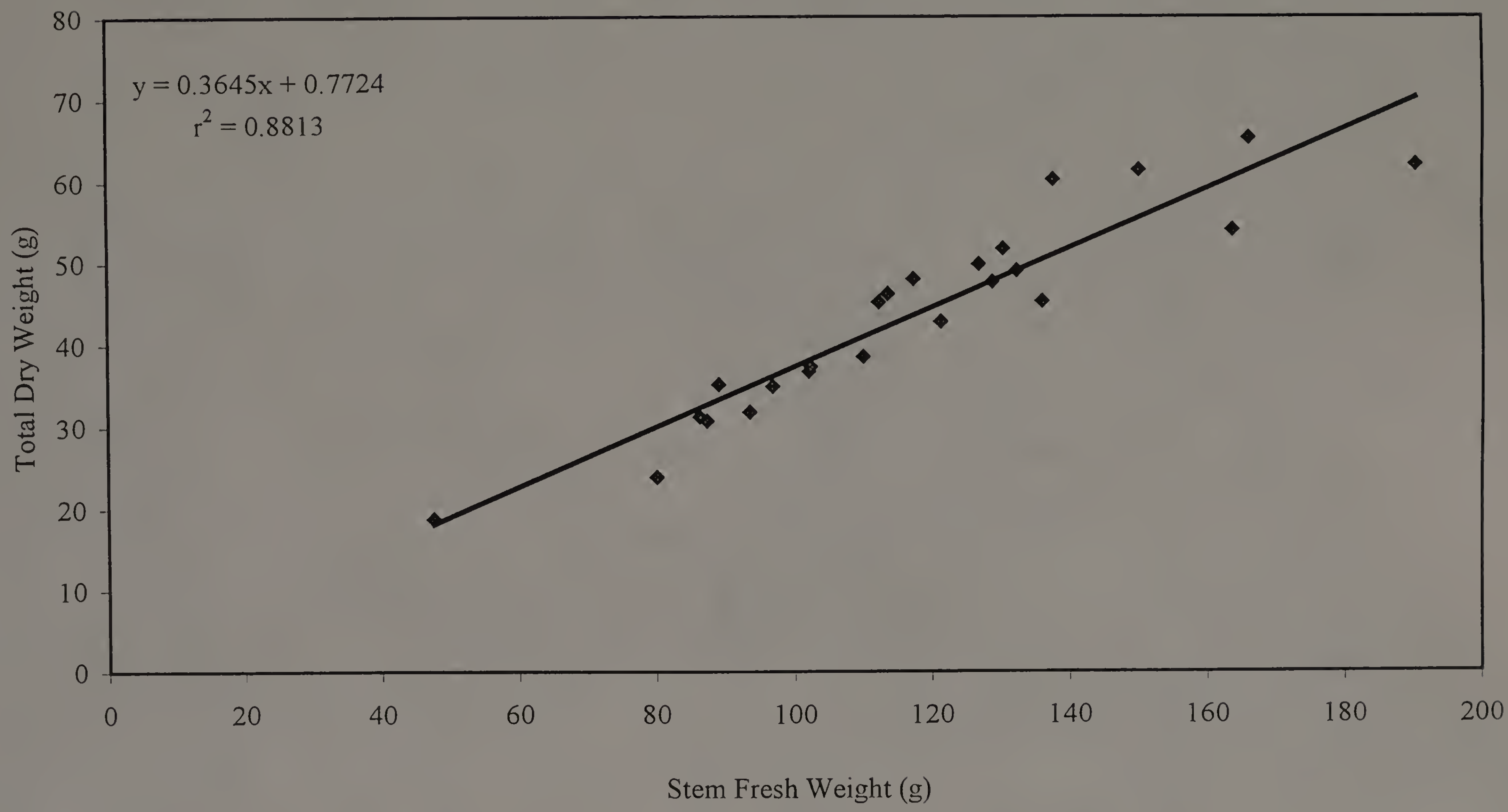


Figure 3.6. Relationship between Stem Fresh Weight and Total Dry Weight for 2nd Experiment

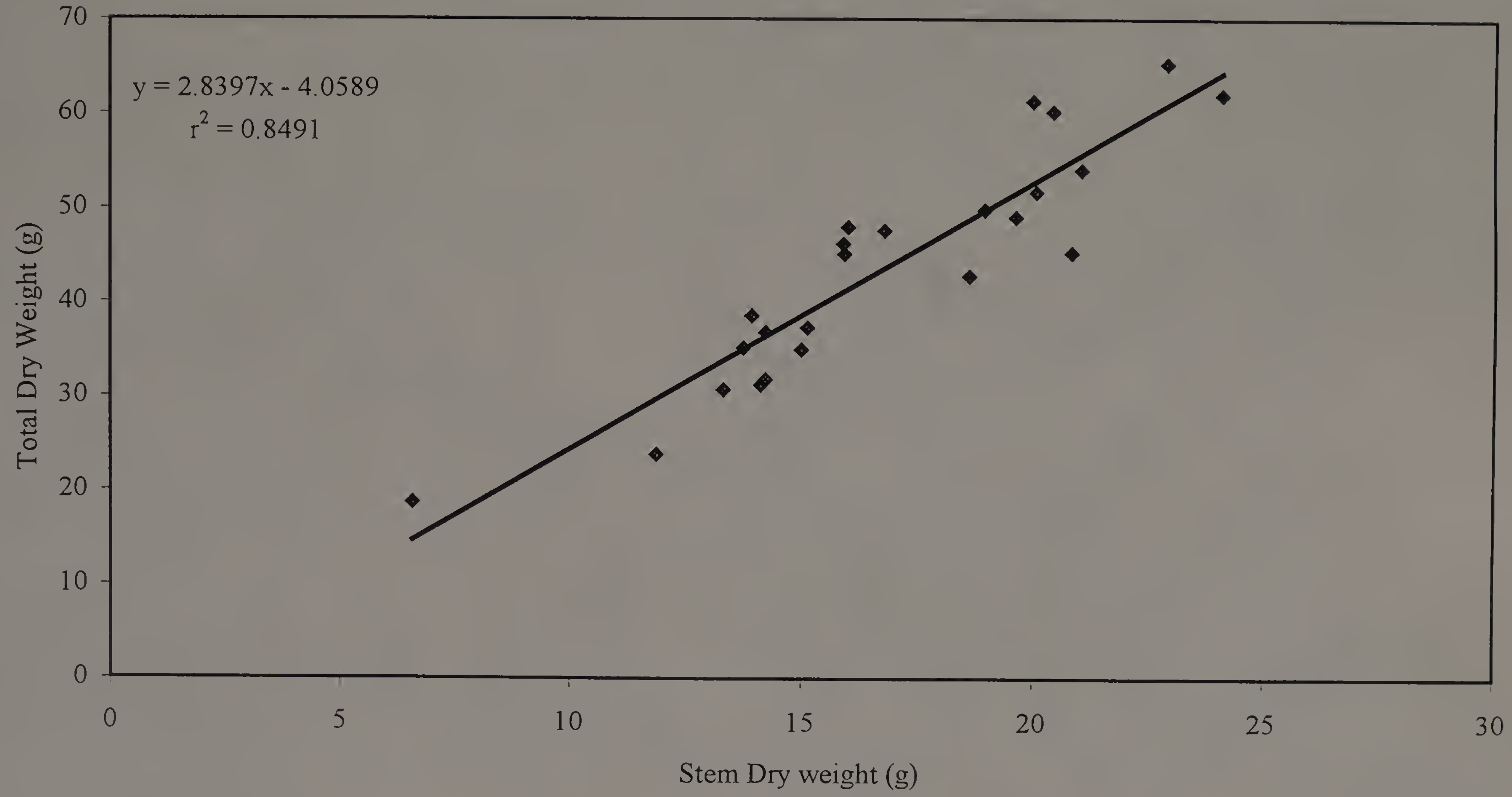


Figure 3.7. Relationship between Stem Dry Weight and Total Dry Weight for 2nd Experiment

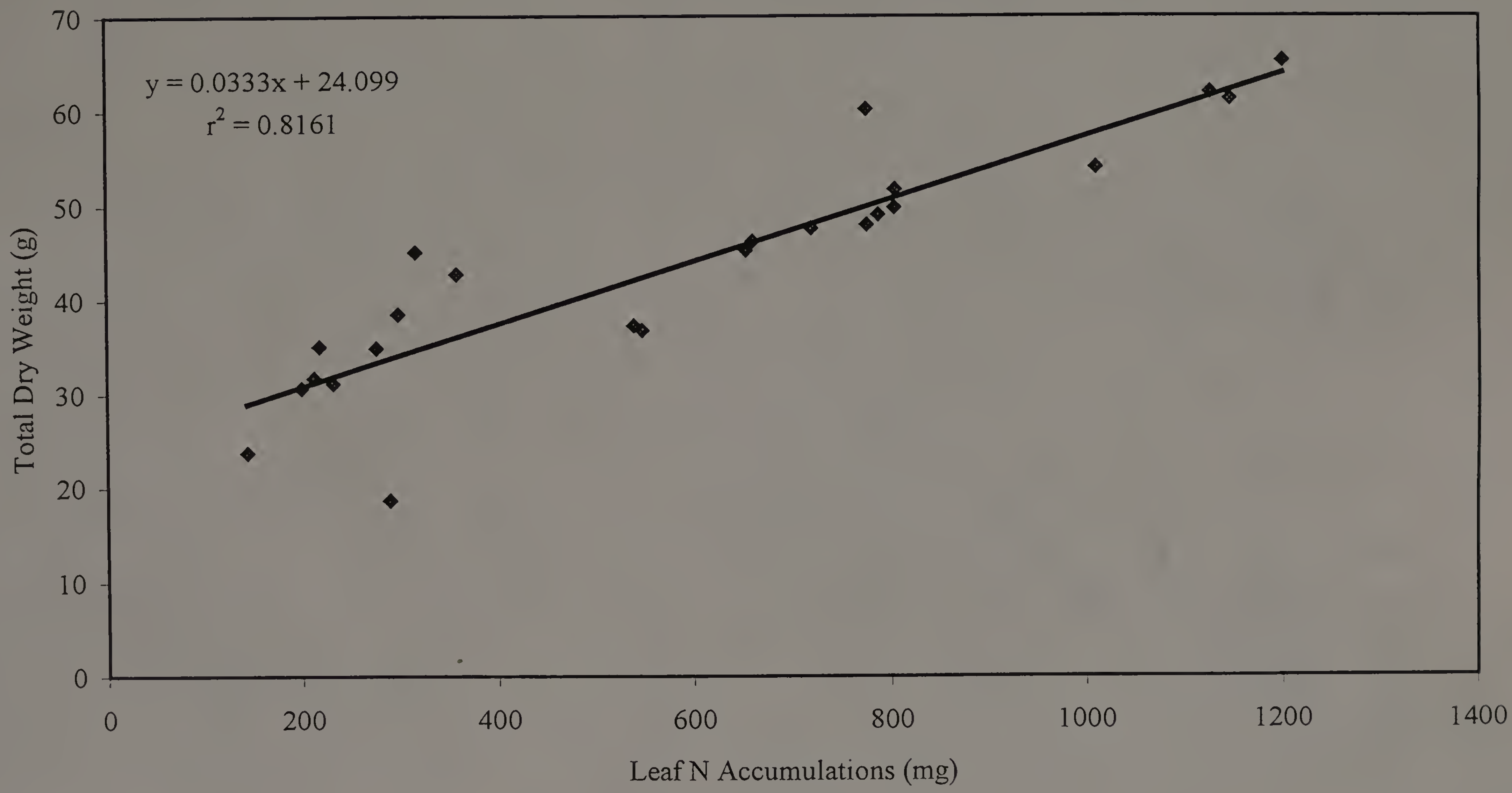


Figure 3.8. Relationship between Leaf N Accumulations and Total Dry Weight for 2nd Experiment

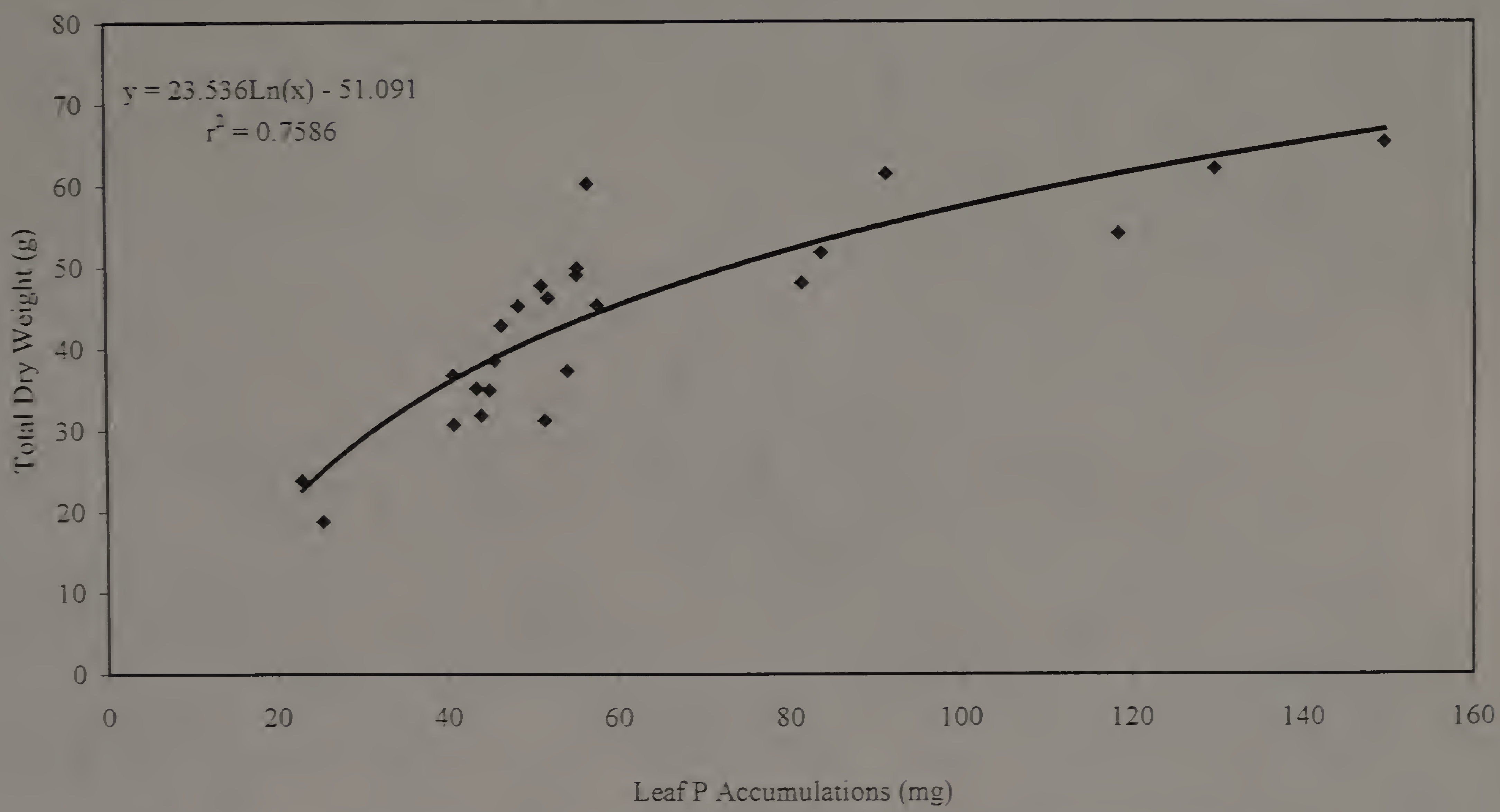


Figure 3.9. Relationship between Leaf P Accumulations and Total Dry Weight for 2nd Experiment

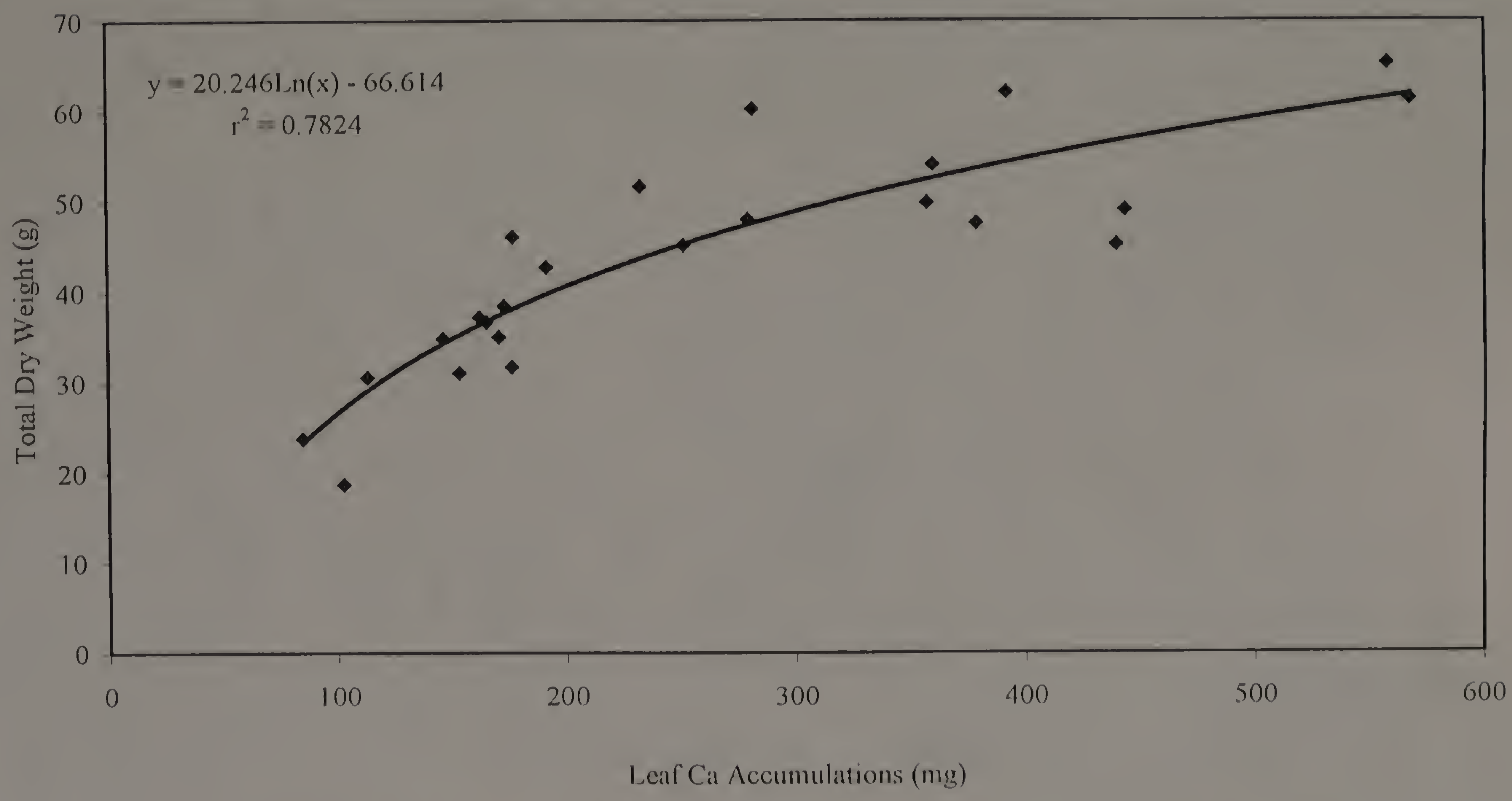


Figure 3.10. Relationship between Leaf Ca Accumulations and Total Dry Weight for 2nd Experiment

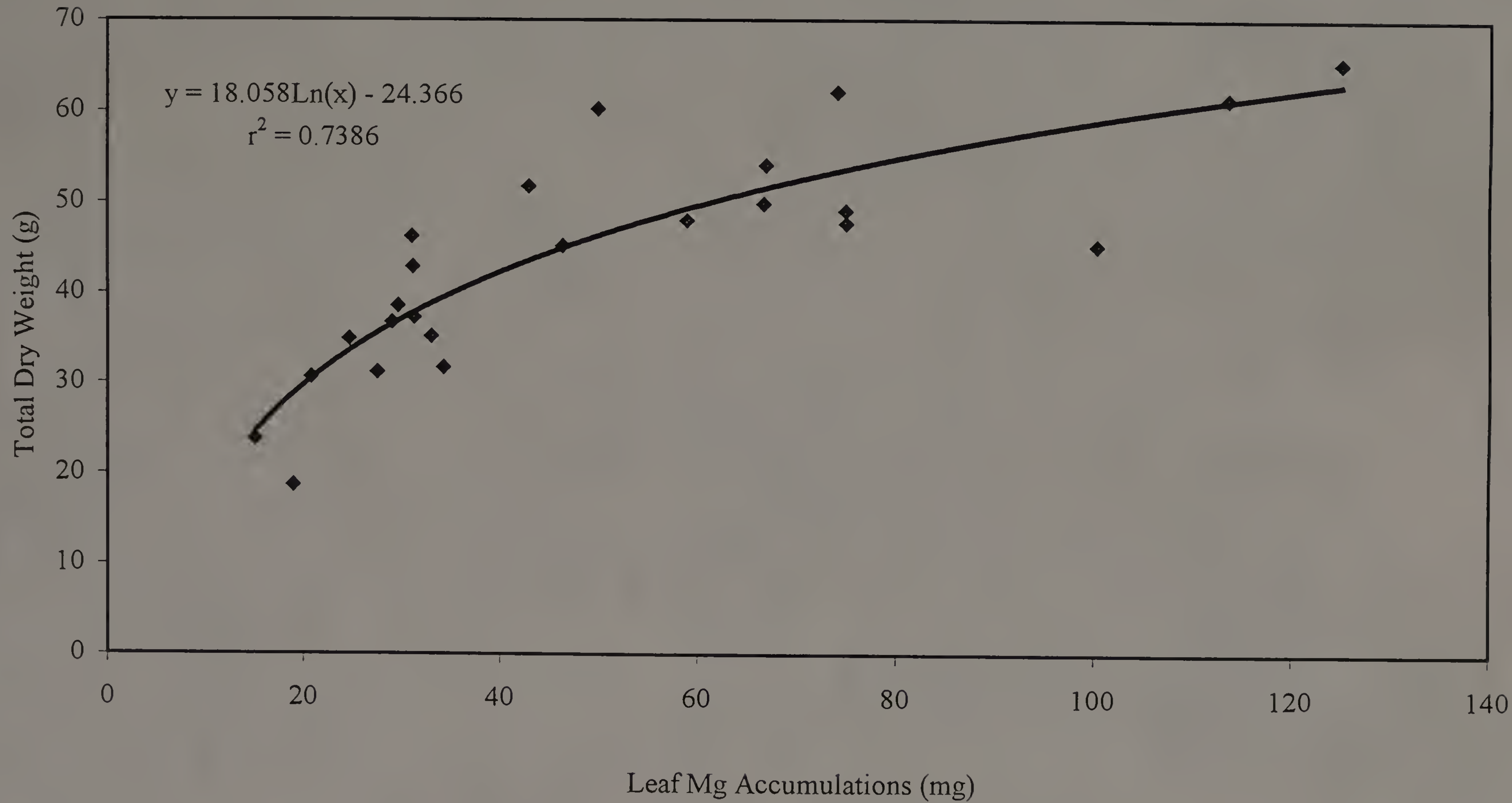


Figure 3.11. Relationship between Leaf Mg Accumulations and Total Dry Weight for 2nd Experiment

CHAPTER 4

EFFECTS OF DIFFERENT DOSAGES OF K ON TOMATO GROWTH AND SOIL FERTILITY

4.1 Introduction

The previous experiment (Chapter 3) showed that K was effective in reducing phytotoxicity of immature compost with high NH_4 content, especially when high amount of immature compost was used in the container medium. This experiment was designed to determine the effects of variable amounts of K on reducing the phytotoxicity of NH_4 in immature compost.

4.2 Materials and Methods

4.2.1 Materials

As in the previous experiment (Chapter 3), a compost of biosolids and wood chips was treated with $(NH_4)_2SO_4$ to 2,000 mg N kg^{-1} to simulate an immature compost. The same compost without any ammonium added was used as mature compost. A soil (sandy loam) was used as a modifier. Again tomato plants (<u>Lycopersicon</u> <u>esculentum</u> Mill.) were employed as an indicator crop based the reasons mentioned in chapter 1.

Use of synthetic immature compost instead of a natural one was for quality control, as mentioned before, many factors can attribute to compost immaturity, and NH_4 can vary with time and handling in storage. Previous research has shown that 2,000 mg NH_4^+-N kg^{-1} is a common concentration in fresh immature compost (O'Brien and Barker, 1995).

4.2.2 Methods

In both composts, different proportions (regimes) of compost and soil were used at the ratios of 1:2 and 1:11 by volume (compost:soil). Each regime received treatments of K at rate of 0.0, 0.3, 0.6 and 0.9 g K kg^{-1} media. Four replications were randomly arranged. Tomato grew in a greenhouse for about six weeks from seedlings until fruit initiation. The growth indices such as plant height, numbers flower, fruit, and leaf, weights of fresh and dry fruit, fresh and dry leaf, and fresh and dry stem, and total dry plant weight were recorded. Dried plant and soil samples were prepared with the same procedures used in section 2.2.2 for N, P, K, Ca, and Mg analysis.

4.3 Results

4.3.1 Effects of Different Dosages of K on Tomato Growth

Tables 4.1, 4.2, and 4.3 provide information about how different dosages of K affected tomato growth. Eleven growth indices were measured, including plant height, numbers of flower, fruit, and leaf, fresh and dry weights of fruit, leaf, and stem, and total plant dry weight.

4.3.1.1 Tomato Plant Height

4.3.1.1.1 Analysis of Overall Effects of the Two Compost Media

The two compost media showed significantly different effects on plant height (Table 4.1). The mature medium generated plants with an average height of 95 cm. The immature medium produced an average plant height of 88 cm.

Different regimes showed no significant different effects on plant height (Table 4.1). The averages were 92 cm in the low proportion of compost and 90 cm in the high proportion.

Fertilization with different dosages of K did not significantly affect plant height (Table 4.1). The average was 91 cm, ranging from 87 to 94 cm.

4.3.1.1.2 Analysis of Effects of the Mature Compost Medium

No significant difference occurred between the regimes in the mature compost medium (Table 4.2). The average plant heights were 97 cm in the high proportion of compost and 93 cm in the low proportion.

No significant differences existed among the K dosages in the mature compost medium (Table 4.2). The average plant height was 95 cm, ranging from 90 to 99 cm.

The interaction of K level with regime in the mature medium was significant.

All K additions increased plant heights in both regimes (Table 4.3). In the low proportion of compost, plant height increased by 4.6% in the dosage of 0.3g K/kg media, by 13.2% in the dosage of 0.6g K/kg media, and by 10.0% in the dosage of 0.9g K/kg media. In the high proportion, plant height increased by 4.0% in the dosage of 0.3g K/kg media, by 7.0% in the dosage of 0.6g K/kg media, and by 1.9% in the dosage of 0.9g K/kg media.

It seemed that the increases in the low proportion of compost were slightly higher than those increases in the high proportion of compost.

4.3.1.1.3 Analysis of Effects of the Immature Compost Medium

A significant difference existed between the regimes in the immature compost medium (Table 4.2). The average plant heights were 91 cm in the low proportion of compost and 84 cm in the high proportion.

No significant differences existed among the K dosages in the immature compost medium (Table 4.2). The average plant height was 88 cm, ranging from 84 to 90 cm.

In the immature compost medium, all K additions increased plant heights in both regimes (Table 4.3). In the low proportion of compost, the plant height increased by

0.6% in the dosages of 0.3g and 0.6g K/kg media, and by 4.2% in the dosage of 0.9g K/kg media. In the high proportion, the plant height increased by 11.6% in the dosage of 0.3g K/kg media, by 12.3% in the dosage of 0.6g K/kg media, and by 11.9% in the dosage of 0.9g K/kg media.

4.3.1.2 Tomato Flower Numbers

4.3.1.2.1 Analysis of Overall Effects of the Two Compost Media

There was no significant difference between the mature and immature media (Table 4.1). The average numbers of flower were 52 in the immature medium and 51 in the mature medium.

Different regimes showed no significant different effects on numbers of flower (Table 4.1). The low proportion of compost produced an average of 50 flowers per plant, and the high proportion produced an average of 53 flowers.

Fertilization with different dosages of K affected numbers of flower differently (Table 4.1). The dosage of 0.6g K/kg media produced the highest numbers of flower, averaging 60. The treatment with no K addition produced the least numbers of flower, averaging 45. The dosages of 0.9 and 0.3g K/kg media statistically produced the same numbers of flower, averaging 50 per plant.

4.3.1.2.2 Analysis of Effects of the Mature Compost Medium

No significant difference existed between the regimes in the mature compost medium (Table 4.2). The average numbers of flower were 53 per plant in the high proportion of compost and 49 in the low proportion.

No significant differences existed among the K dosages in the mature compost medium (Table 4.2). The average numbers of flower were 51, ranging from 46 to 59.

However K dosages and regime interacted to affect the numbers of flower.

In the mature compost medium, all K additions increased numbers of flower except for one in each regime, which were the dosage of 0.3g K/kg media in the low proportion of compost and the dosage of 0.9g K/kg media in the high proportion (Table 4.3). The above dosages decreased numbers of flower by 1.9% and by 14.0%, respectively. Otherwise in the low proportion of compost, K addition increased numbers of flower by 63.9% in the dosage of 0.6g K/kg media, and by 41.9% in the dosage of 0.9g K/kg media. In the high proportion, additions of K increased numbers of flower by 8.8% in the dosage of 0.3g K/kg media, and by 1.9% in the dosage of 0.6g K/kg media.

4.3.1.2.3 Analysis of Effects of the Immature Compost Medium

No significant differences in numbers of flower occurred between the regimes in the immature compost medium (Table 4.2). The average numbers of flower were 53 in the high proportion of compost and 51 in the low proportion.

There were significant differences among the K dosages in the immature compost medium (Table 4.2). The dosage of 0.6g K/kg media produced the highest numbers of flower, averaging 60 per plant. The no K addition media produced the least numbers of flowers, averaging 44. The dosages of 0.9 and 0.3g K/kg media statistically produced the same numbers of flower, averaging 52.

In the immature compost medium, all additions of K increased numbers of flower in both regimes (Table 4.3). In the low proportion of compost, the numbers of flower increased by 1.6% in the dosage of 0.3 g K/kg media, by 27.9% in the dosage of 0.6 g K/kg media, and by 3.2% in the dosage of 0.9 g K/kg media. In the high proportion, the numbers of flower increased by 24.8% in the dosage of 0.3 g K/kg media, by 49.1% in the dosage of 0.6 g K/kg media, and by 47.8% in the dosage of 0.9 g K/kg media.

4.3.1.3 Tomato Fruit Numbers

4.3.1.3.1 Analysis of Overall Effects of the Two Compost Media

A significant difference existed between the mature and immature media (Table 4.1). The mature medium produced an average of 4.9 fruits per plant, and the immature medium produced an average of 3.4 fruits.

No significant differences occurred between the regimes. The low and high proportion of compost statistically produced the same numbers of fruit, averaging 4.2 per plant (Table 4.1).

Fertilization showed no significant differences (Table 4.1). The average numbers of fruit were 4.2, ranging from 3.1 to 4.8.

4.3.1.3.2 Analysis of Effects of the Mature Compost Medium

No significant differences occurred between the regimes in the mature compost medium (Table 4.2). The average numbers of fruit were 5.0 per plant in the low proportion of compost and 4.8 in the high proportion.

No significant differences occurred among fertilization treatments in the mature compost medium (Table 4.2). The average numbers of fruit were 4.9 per plant, ranging from 3.6 to 5.8.

In the mature compost medium, the treatments with K addition produced higher or equal numbers of fruit than/to the treatment without K addition (Table 4.3). In the low proportion of compost, the addition of K increased numbers of fruit by 78.6% in the dosage of 0.3g K/kg media, by 28.6% in the dosage of 0.6g K/kg media, and by 64.3% in the dosage of 0.9g K/kg media. In the high proportion, the addition of K produced the same numbers of fruit in the dosages of 0.3 and 0.0g K/kg media. But the addition of K increased numbers of fruit by 86.7% in the dosage of 0.6g K/kg media, and by 26.7% in the dosage of 0.9g K/kg media.

4.3.1.3.3 Analysis of Effects of the Immature Compost Medium

No significant difference occurred between the regimes in the immature compost medium (Table 4.2). The average numbers of fruit were 3.4 per plant in both regimes.

Also no significant differences occurred among fertilization treatments in the immature compost medium (Table 4.2). The average numbers of fruit were 3.4 per plant, ranging from 2.6 to 4.3.

The dosages had different effects on numbers of fruit in each regime (Table 4.3). In the low proportion of compost, the dosage of 0.3 g K/kg media decreased numbers of fruit by 27.3%. Otherwise, K addition increased numbers of fruit by 63.6% apiece in the dosages of 0.6 and 0.9 g K/kg media. In the high proportion, the K addition increased numbers of fruit by 80.0% in the dosage of 0.3 g K/kg media, by 10.0% in the dosage of 0.6 g K/kg media, and by 60.0% in the dosage of 0.9 g K/kg media.

4.3.1.4 Tomato Fruit Fresh Weight

4.3.1.4.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The mature medium produced an average of 105 g of fresh tomato, and the immature medium produced an average of 38 g per plant.

No overall significant difference occurred between the regimes (Table 4.1). The average weights of fresh fruit were 83 g per plant in the low proportion of compost and 60 g in the high proportion.

Differences occurred among the fertilization treatments (Table 4.1). The dosage of 0.6 g K/kg media produced the highest weight of fresh fruit averaging 100 g per plant. The media without K addition produced the least fruit fresh weight, averaging 38 g. The dosages of 0.9 and 0.3 g K/kg media statistically produced the same fruit fresh weights averaging 74 g.

4.3.1.4.2 Analysis of Effects of the Mature Compost Medium

No significant difference existed between the regimes in the mature compost medium (Table 4.2). The average weights of fresh fruit were 119 g per plant in the low proportion of compost, and 91 g in the high proportion.

There were statistical differences among the fertilizer treatments in the mature compost medium (Table 4.2). The dosage of 0.6 g K/kg media produced the highest weight of fresh fruit, averaging 165 g. No K addition media produced the least weight of fresh fruit, averaging 51 g. The dosages of 0.9 and 0.3 g K/kg media produced the same fresh fruit weights, averaging 102 g.

All K additions increased fruit fresh weight in the mature compost medium (Table 4.3). In the low proportion of compost, the increases were by 277% in the dosage of 0.3 g K/kg media, by 485% in the dosage of 0.6 g K/kg media, and by 183% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 7.6% in the dosage of 0.3 g K/kg media, by 86.0% in the dosage of 0.6 g K/kg media, and by 58.3% in the dosage of 0.9 g K/kg media.

4.3.1.4.3 Analysis of Effects of the Immature Compost Medium

No significant difference existed between regimes in the immature compost medium (Table 4.2). The average weights of fresh fruit were 47 g per plant in the low proportion of compost and 29 g in the high proportion.

No significant differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The average weights of fresh fruit were 38 g, ranging from 25 to 53 g. However the interaction with regimes was significant.

In the immature compost medium, all K additions increased fruit fresh weight in the low proportion of compost (Table 4.3). The increases were by 35.2% in the dosage of 0.3 g K/kg media, by 72.8% in the dosage of 0.6 g K/kg media, and by 92.0% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 80.5% in the dosage of 0.3 g K/kg media, and by 134% in the dosage of 0.9 g K/kg media. However the fruit fresh weight decreased by 9.1% in the dosage of 0.6 g K/kg media.

4.3.1.5 Tomato Fruit Dry Weight

4.3.1.5.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The mature medium generated an average of 7.9 g of dry fruit, and the immature medium generated an average of 3.4 g.

No overall significant difference occurred between the regimes (Table 4.1). The average weights of dry fruit were 6.4 g in the low proportion of compost and 4.9 g in the high proportion.

Some differences occurred among the fertilization treatments (Table 4.1). The dosage of 0.6 g K/kg media produced the highest weight of dry fruit, averaging 7.3 g per plant. The media without K addition produced the least weight of dry fruit, averaging 3.1 g. The dosages of 0.9 and 0.3 g K/kg media statistically produced the same weights of dry fruit, averaging 6.0 g.

4.3.1.5.2 Analysis of Effects of the Mature Compost Medium

No significant difference occurred between the regimes in the mature compost medium (Table 4.2). The average weights of dry fruit were 8.8 g in the low proportion of compost and 7.0 g in the high proportion.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The dosage of 0.6 g K/kg media produced the highest weight of dry fruit, averaging 11.6 g. No K addition media produced the least weight of dry fruit, averaging 3.9 g. The dosages of 0.9 and 0.3 g K/kg media statistically produced the same weights of dry fruit, averaging 8.0 g.

All K additions increased fruit dry weight in the mature compost medium (Table 4.3). In the low proportion of compost, the increases were by 242% in the dosage of 0.3 g K/kg media, by 355% in the dosage of 0.6 g K/kg media, and by 151% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 12.6% in the dosage of 0.3 g K/kg media, by 93.2% in the dosage of 0.6 g K/kg media, and by 73.1% in the dosage of 0.9 g K/kg media.

4.3.1.5.3 Analysis of Effects of the Immature Compost Medium

No significant difference occurred between regimes in the immature compost medium (Table 4.2). The average weights of dry fruit were 3.9 g per plant in the low proportion of compost and 2.8 g in the high proportion.

No significant differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The average weights of dry fruit were 3.4 g, ranging from 2.3 to 4.8 g.

In the immature compost medium, all K additions increased the dry fruit weight in the low proportion of compost (Table 4.3). The increases were by 29.1% in the dosage of 0.3 g K/kg media, by 57.9% in the dosage of 0.6g K/kg media, and by 80.9% in the dosage of 0.9 g K/kg media. In the high proportion, the fruit dry weight increased by 96.6% in the dosage of 0.3 g K/kg media, and by 157% in the dosage of 0.9 g K/kg media. However the fruit dry weight decreased by 4.6% in the dosage of 0.6 g K/kg media (Table 4.3).

4.3.1.6 Tomato Leaf Numbers

4.3.1.6.1 Analysis of Overall Effects of the Two Compost Media

No significant difference occurred between the mature and immature media (Table 4.1). The average numbers of leaf were 35 per plant in both media.

Also no overall significant difference occurred between the regimes (Table 4.1). The average numbers of leaf were 36 per plant in the high proportion of compost and 34 in the low proportion.

No overall significant differences occurred among the fertilization treatments (Table 4.1). The average numbers of leaf were 35 per plant.

4.3.1.6.2 Analysis of Effects of the Mature Compost Medium

No significant difference occurred between the regimes in the mature compost medium (Table 4.2). The average numbers of leaf were 36 per plant in the high proportion of compost and 34 in the low proportion of compost.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The no K addition media produced the highest numbers of leaf, averaging 38. The dosage of 0.6 g K/kg media produced the least numbers of leaf, averaging 32. The dosages of 0.3 and 0.9 g K/kg media statistically produced the same numbers of leaf, averaging 35.

Except for the dosage of 0.3 g K/kg media in the high proportion of compost, which increased numbers of leaf by 9.5%, all other K additions decreased numbers of leaf (Table 4.3). In the low proportion of compost, the decreases were by 18.5% in the dosage of 0.3 g K/kg media, by 24.2% in the dosage of 0.6 g K/kg media, and by 12.7% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 9.5% in the dosage of 0.6 g K/kg media, and by 8.8% in the dosage of 0.9g K/kg media.

4.3.1.6.3 Analysis of Effects of the Immature Compost Medium

No significant difference occurred between the regimes in the immature compost medium (Table 4.2). The average numbers of leaf were 36 per plant in the high proportion of compost and 34 in the low proportion.

Also no significant differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The average numbers of leaf were 35 per plant, ranging from 32 to 37. However, the interaction of fertilization and regimes was significant.

Except for the dosage of 0.3 g K/kg media in the low proportion of compost, which decreased the numbers of leaf by 5.3%, all K additions increased numbers of leaf (Table 4.3). In the low proportion of compost, the increases were by 8.3% in the dosage of 0.6 g K/kg media, and by 1.5% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 16.7% in the dosage of 0.3 g K/kg media, by 20.6% in the dosage of 0.6 g K/kg media, and by 18.3% in the dosage of 0.9 g K/kg media.

The high proportion of compost had higher increases in numbers of leaf.

4.3.1.7 Tomato Leaf Fresh Weight

4.3.1.7.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The immature medium produced leaf fresh weight with an average of 163 g per plant, and the mature medium produced an average of 136 g.

There was also a significant difference between the regimes (Table 4.1). The high proportion of compost produced leaf fresh weight with an average of 160 g per plant. The low proportion produced an average of 139 g.

No overall significant differences occurred among fertilization treatments (Table 4.1). The average weights of fresh leaf were 149 g per plant, ranging from 143 to 155g.

4.3.1.7.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.2). The average weights of fresh leaf per plant were 145 g in the high proportion of compost and 126 g in the low proportion.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The no K addition media produced the highest weight of fresh leaves averaging 160 g. The dosages of 0.3 and 0.6 g K/kg media statistically produced the same weight of fresh leaves averaging 122 g. The dosage of 0.9 g K/kg media produced an average of 138g.

4.3.1.8 Tomato Leaf Dry Weight

4.3.1.8.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The immature medium produced leaf dry weight with an average of 18.5 g per plant, and the mature medium produced an average of 16.5 g.

There was a significant difference between the regimes (Table 4.1). The high proportion of compost produced leaf dry weight averaging 18.5 g per plant. The low proportion produced an average of 16.5 g.

No overall significant differences occurred among fertilization treatments (Table 4.1). The average weights of dry leaf were 17.5 g per plant, ranging from 16.9 to 17.9 g.

4.3.1.8.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.2). The average weights of dry leaf were 17.5 g in the high proportion of compost and 15.4 g in the low proportion.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The no K addition media produced the highest weight of dry leaf averaging 19.3 g. The dosages of 0.3 and 0.6 g K/kg media statistically produced the same weights of dry leaf averaging 14.8 g. The dosage of 0.9 g K/kg media produced an average of 17.0 g.

Except for the dosage of 0.9 g K/kg media in the high proportion of compost, which increased the leaf dry weight by 1.1%, all K additions decreased leaf dry weight (Table 4.3). In the low proportion of compost, the decreases were by 27.8% in the dosage of 0.3 g K/kg media, by 34.8% in the dosage of 0.6 g K/kg media, and by 25.1%

in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 14.7% in the dosage of 0.3 g K/kg media, and by 17.0% in the dosage of 0.6 g K/kg media.

4.3.1.8.3 Analysis of Effects of the Immature Compost Medium

No significant difference occurred between the regimes in the immature compost medium (Table 4.2). The high proportion of compost produced an average of 19.4 g of dry leaf per plant, and the low proportion produced an average of 17.6 g.

No differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The average weights of dry leaf were 18.5 g, ranging from 16.3 to 20.3 g. However, some interactions occurred within the regimes.

Except for the dosage of 0.3 g K/kg media in the low proportion of compost, which decreased leaf dry weight by 0.6%, all K additions increased leaf dry weight (Table 4.3). In the low proportion of compost, the increases were by 27.3% in the dosage of 0.6 g K/kg media, and by 1.6% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 29.5% in the dosage of 0.3 g K/kg media, by 21.1% in the dosage of 0.6 g K/kg media, and by 29.3% in the dosage of 0.9 g K/kg media.

4.3.1.9 Tomato Stem Fresh Weight

4.3.1.9.1 Analysis of Overall Effects of the Two Compost Media

No overall significant difference occurred between the mature and immature media (Table 4.1). The average weights of fresh stem were 78 g in the mature medium and 72 g in the immature medium.

Also no overall significant difference occurred between the regimes (Table 4.1). The average weights of fresh stem were 75 g in the both regimes.

There were no overall significant differences among the fertilization treatments (Table 4.1). The average weights of fresh stem were 75 g, ranging from 73 to 79 g.

4.3.1.9.2 Analysis of Effects of the Mature Compost Medium

There was no significant difference between the regimes in the mature compost medium (Table 4.2). The average weights of fresh stem were 81 g in the high proportion of compost and 74 g in the low proportion.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The media with no K addition produced the highest weights of fresh stem, averaging 95 g. The dosages of 0.9 and 0.6 g K/kg media statistically produced the same weights of fresh stem, averaging 70 g. The dosage of 0.3 g K/kg media produced an average of 76 g of fresh stem.

In the mature compost medium, all K additions decreased the stem fresh weight (Table 4.3). In the low proportion of compost, the decreases were by 38.5% in the dosage of 0.3 g K/kg media, by 43.1% in the dosage of 0.6 g K/kg media, and by 28.4% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 0.3% in the dosage of 0.3 g K/kg media, by 16.7% in the dosage of 0.6 g K/kg media, and by 15.5% in the dosage of 0.9 g K/kg media.

4.3.1.9.3 Analysis of Effects of the Immature Compost Medium

No significant difference existed between the regimes in the immature compost medium (Table 4.2). The average weights of fresh stem were 76 g in the low proportion of compost and 69 g in the high proportion.

Some differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The dosage of 0.6 g K/kg media produced the highest weight of fresh stem, averaging 81 g. The no K addition media produced an average of 63 g of fresh stem. The dosages of 0.3 and 0.9 g K/kg media statistically produced the same weight of fresh stem, averaging 73 g.

In the immature compost medium, all K additions increased the stem fresh weight (Table 4.3). In the low proportion of compost, the increases were by 5.2% in the dosage of 0.3 g K/kg media, by 17.8% in the dosage of 0.6 g K/kg media, and by 0.4% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 31.8% in the dosage of 0.3 g K/kg media, by 42.4% in the dosage of 0.6 g K/kg media, and by 34.1% in the dosage of 0.9 g K/kg media.

4.3.1.10 Tomato Stem Dry Weight

4.3.1.10.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The mature medium produced stem dry weight with an average of 11.5 g, and the immature medium produced an average of 9.0 g.

No overall significant difference occurred between the regimes (Table 4.1). The average weights of dry stem were 10.1 g in the high proportion of compost and 10.4 g in the low proportion.

Also no overall significant differences occurred among the fertilization treatments (Table 4.1). The average weights of dry stem were 10.2 g, ranging from 9.5 to 11.1 g.

4.3.1.10.2 Analysis of Effects of the Mature Compost Medium

No significant difference existed between the regimes in the mature compost medium (Table 4.2). The average weights of dry stem were 11.7 g in the high proportion of compost and 11.3 g in the low proportion.

Some differences occurred among the fertilization treatments in the mature compost medium (Table 4.2). The no K addition media produced the highest weight of dry stem, averaging 14.6 g. All other K additions statistically produced the same weight of dry stem averaging 10.4 g, ranging from 9.6 to 11.3 g.

In the mature compost medium, all K additions decreased the stem dry weight (Table 4.3). In the low proportion of compost, the decreases were by 37.7% in the dosage of 0.3 g K/kg media, by 45.1% in the dosage of 0.6 g K/kg media, and by 32.3% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 4.4% in the dosage of 0.3 g K/kg media, by 20.9% in the dosage of 0.6 g K/kg media, and by 23.7% in the dosage of 0.9 g K/kg media.

4.3.1.10.3 Analysis of Effects of the Immature Compost Media

There was no significant difference between the regimes in the immature compost medium (Table 4.2). The average weights of dry stem were 9.5 g in the low proportion of compost and 8.5 g in the high proportion of compost.

Some differences occurred among the fertilization treatments in the immature compost medium (Table 4.2). The dosage of 0.6 g K/kg media produced the highest weights of dry stem, averaging 10.4 g. The no K addition media produced an average of 7.6 g dry stem. The dosages of 0.3 and 0.9 g K/kg media statistically produced the same weights of dry stem, averaging 9.0 g.

In the immature compost medium, all K additions increased the stem dry weight (Table 4.3). In the low proportion of compost, the increases were by 9.9% in the dosage of 0.3 g K/kg media, by 35.3% in the dosage of 0.6 g K/kg media, and by 2.8% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 38.7% in the dosage of 0.3 g K/kg media, by 38.5% in the dosage of 0.6 g K/kg media, and by 28.2% in the dosage of 0.9 g K/kg media.

4.3.1.11 Tomato Total Dry Weight

4.3.1.11.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.1). The mature medium produced an average of 35.8 g of total dry weight per plant, and the immature medium produced an average of 30.9 g.

No overall significant difference occurred between the regimes (Table 4.1). The average total dry weights were 33.5 g in the high proportion of compost and 33.2 g in the low proportion.

No overall differences occurred among fertilization treatments (Table 4.1). The average total dry weights were 33.4 g, ranging from 32.0 to 34.6 g per plant.

4.3.1.11.2 Analysis of Effects of the Mature Compost Medium

No significant difference existed between the regimes in the mature compost medium (Table 4.2). The average total dry weights were 36.2 g in the high proportion of compost and 35.4 g in the low proportion.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 4.2). The average total dry weights were 35.8 g, ranging from 34.4 to 37.8 g per plant.

In the mature compost medium, except for the dosage of 0.9 g K/kg media in the high proportion of compost, which slightly increased total dry weight by 1.6%, all K additions decreased total dry weight (Table 4.3). In the low proportion of compost, the decreases were by 10.5% in the dosage of 0.3 g K/kg media, by 8.2% in the dosage of 0.6

g K/kg media, and by 14.2% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 7.5% in the dosage of 0.3 g K/kg media, and by 4.0% in the dosage of 0.6 g K/kg media.

4.3.1.11.3 Analysis of Effects of the Immature Compost Medium

No significant difference existed between the regimes in the immature compost medium (Table 4.2). The average total dry weights were 31.1 g in the low proportion of compost and 30.7 g in the high proportion.

Some differences existed among the fertilization treatments in the immature compost medium (Table 4.2). The dosage of 0.6 g K/kg media produced the highest total dry weight, averaging 33.7 g. The no K addition media produced the least amount of total dry weight, averaging 26.2 g. The dosages of 0.9 and 0.3 g K/kg media statistically produced the same total dry weights, averaging 31.9.

In the immature compost medium, all K additions increased total dry weight (Table 4.3). In the low proportion of compost, the increases were by 5.6% in the dosage of 0.3 g K/kg media, by 32.9% in the dosage of 0.6 g K/kg media, and by 10.0% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 36.8% in the dosage of 0.3 g K/kg media, by 24.1% in the dosage of 0.6 g K/kg media, and by 38.1% in the dosage of 0.9 g K/kg media.

4.3.1.12 Various Growth Index vs. Total Plant Dry Weight

There was a significantly highly positive correlation between stem dry weight and total plant dry weight with a linear regression coefficient of 0.53 (Figure 4.1).

There was no significant correlation between each of all other growth indices and total plant dry weight (The tabulated regression coefficients r are 0.606 at 0.01 level, and 0.482 at 0.05 level when sample size n=16).

The vegetative parts of the plant were, as with the results in other two experiments, still the major contributors to the total dry weight. However, it was difficult to use some of those parameters to predict plant production because the poor relationships between the most of growth indices and total plant dry weight.

4.3.2 Effects of Different Dosages of K on Leaf Nutrient Accumulations

Tables 4.4, 4.5 and 4.6 show the total nutrient accumulations in plant leaves. There was poor correlation between each of individual nutrient accumulation and total plant dry weight. Five major nutrients were measured, including N, P, K, Ca, and Mg.

4.3.2.1 Nitrogen

4.3.2.1.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.4). The average N accumulations were 730 mg per plant in the immature medium and 458 mg in the mature medium.

A significant difference occurred between the regimes (Table 4.4). The average N accumulation was 664 mg in the high proportion of compost and 524 mg in the low proportion.

No overall significant differences existed among the fertilization treatments (Table 4.4). The average N accumulation was 594 mg, ranging from 563 to 621mg per plant.

4.3.2.1.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.5). The average N accumulation was 515 mg in the high proportion of compost and 400 mg in the low proportion.

Some differences existed among the fertilization treatments in the mature compost medium (Table 4.5). The average N accumulation was the highest in the media without K addition, averaging 507 mg. The average N accumulation was statistically the same in dosages of 0.3 and 0.6 g K/kg media, averaging 414 mg. The average N accumulation was 497 mg in the dosage of 0.9 g K/kg media.

In the mature compost medium, except for one K dosage, all K additions decreased N accumulation (Table 4.6). In the low proportion of compost, the decreases were by 31.5% in the dosage of 0.3 g K/kg media, by 29.9% in the dosage of 0.6 g K/kg media, and by 16.9% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 7.6% in the dosage of 0.3 g K/kg media, and 5.6% in the dosage of 0.6 g K/kg media. However N accumulation increased by 12.2% in the dosage of 0.9 g K/kg media.

4.3.2.1.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.5). The average N accumulation was 813 mg in the high proportion of compost and 648 mg in the low proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.5). The average accumulation of N was 731 mg, ranging from 654 to 805 mg.

In the immature compost medium, all K additions increased N accumulation (Table 4.6). In the low proportion of compost, the increases were by 3.1% in the dosage of 0.3 g K/kg media, by 35.2% in the dosage of 0.6 g K/kg media, and by 6.4% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 15.2% in the dosage of 0.3 g K/kg media, by 13.5% in the dosage of 0.6 g K/kg media, and by 20.6% in the dosage of 0.9 g K/kg media.

4.3.2.2 Phosphorus

4.3.2.2.1 Analysis of Overall Effects of the Two Compost Media

No significant difference existed between the mature and immature media (Table 4.4). The average P accumulation was 67 mg in the immature medium and 63 mg in the mature medium.

A significant difference existed between the regimes (Table 4.4). The average P accumulation was 75 mg in the high proportion of compost 56 mg in the low proportion.

No significant differences existed among the fertilization treatments (Table 4.4). The average P accumulation was 65 mg, ranging from 63 to 68 mg.

4.3.2.2.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.5). The average P accumulation was 73 mg in the high proportion of compost 53 mg in the low proportion.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 4.5). The average P accumulation was 63 mg, ranging from 54 to 71 mg.

In the mature compost medium, except for one dosage, all K additions decreased P accumulation (Table 4.6). In the low proportion of compost, the decreases were by 16.7% in the dosage of 0.3 g K/kg media, by 36.4% in the dosage of 0.6 g K/kg media, and by 24.2% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 11.7% in the dosage of 0.3 g K/kg media, and by 14.3% in the dosage of 0.6 g K/kg media. However accumulation of P increased by 6.5% in the dosage of 0.9 g K/kg media.

4.3.2.2.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.5). The average accumulated P was 77 mg in the high proportion of compost 58 mg in the low proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.5). The average P accumulation was 68 mg, ranging from 61 to 71 mg.

In the immature compost medium, except for one dosage, all K additions increased P accumulation (Table 4.6). In the low proportion of compost, the increases were by 18.2% in the dosage of 0.6 g K/kg media, and by 7.3% in the dosage of 0.9 g K/kg media. However the P accumulation decreased by 1.8% in the dosage of 0.3 g K/kg media. In the high proportion, the increases were by 19.7% in the dosage of 0.3 g K/kg media, by 18.2% in the dosage of 0.6g K/kg media, and by 25.8% in the dosage of 0.9g K/kg media.

4.3.2.3 Potassium

4.3.2.3.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.4). The average K accumulation was 569 mg in the immature medium and 491 mg in the mature medium.

No significant difference existed between the regimes (Table 4.4). The average K accumulation was 542 mg in the high proportion of compost and 518 mg in the low proportion.

Some significant differences existed among the fertilization treatments (Table 4.4). In general, the K accumulation increased as the K supply was increased by fertilization. The average K accumulation was the highest in the dosage of 0.9 g K/kg media, averaging 667 mg. The K accumulation was the second highest in the dosage of 0.6 g K/kg media, averaging 590 mg. The average K accumulation was 502 mg in the dosage of 0.3 g K/kg media. The K accumulation was the least in the dosage of 0.0 g K/kg media, averaging 361 mg.

4.3.2.3.2 Analysis of Effects of the Mature Compost Medium

There was no significant difference between the regimes in the mature compost medium (Table 4.5). The average K accumulation was 514 mg in the high proportion of compost and 469 mg in the low proportion.

Some differences existed among the fertilization treatments in the mature compost medium (Table 4.5). Commonly the K accumulation increased as K supply was increased in the media. The average K accumulation was the highest in the dosage of 0.9 g K/kg media, averaging 602 mg. The average K accumulation was statistically the same in the dosages of 0.3 and 0.6 g K/kg media, averaging 458 mg. The average K accumulation was the least in the no K added media, averaging 447 mg.

In the mature compost medium, except for two dosages, all K additions increased K accumulation (Table 4.6). In the low proportion of compost, the K accumulation decreased by 31.6% in the dosage of 0.3 g K/kg media, and by 35.5% in the dosage of 0.6 g K/kg media. However the K accumulation increased by 9.9% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 57.6% in the dosage of 0.3 g K/kg media, by 61.1% in the dosage of 0.6 g K/kg media, and by 73.8% in the dosage of 0.9 g K/kg media.

4.3.2.3.3 Analysis of Effects of the Immature Compost Medium

There was no significant difference between the regimes in the immature compost medium (Table 4.5). The average K accumulation was 571 mg in the high proportion of compost and 567 mg in the low proportion.

Some differences existed among the fertilization treatments in the immature compost medium (Table 4.5). Average K accumulation increased as the K supply increased. The average K accumulation was statistically the same in the dosages of 0.6 and 0.9 g K/kg media, averaging 728 mg. The average K accumulation was the least in the no K added media, averaging 275 mg. The average K accumulation was 544 mg in the dosage of 0.3 g K/kg media.

In the immature compost medium, all K additions increased K accumulation (Table 4.6). In the low proportion of compost, the increases were by 137% in the dosage of 0.3 g K/kg media, by 228% in the dosage of 0.6 g K/kg media, and by 213% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 68.7% in the dosage of

0.3 g K/kg media, by 116% in the dosage of 0.6 g K/kg media, and by 131% in the dosage of 0.9 g K/kg media.

4.3.2.4 Calcium

4.3.2.4.1 Analysis of Overall Effects of the Two Compost Media

No significant difference existed between the mature and immature media (Table 4.4). The average Ca accumulation was 380 mg in the mature medium and 357 mg in the immature medium.

There was a significant difference between the regimes (Table 4.4). The average Ca accumulation was 386 mg in the high proportion of compost and 350 mg in the low proportion.

Some differences existed among the fertilization treatments (Table 4.4). The average Ca accumulation was the highest in the no K addition media, averaging 421 mg. The average Ca accumulation was statistically the same in all other dosages averaging 351 mg and ranging from 346 to 355 mg.

4.3.2.4.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.5). The average Ca accumulation was 410 mg in the high proportion of compost and 349 mg in the low proportion.

Some differences existed among the fertilization treatments in the mature compost medium (Table 4.5). The average Ca accumulation was the highest in the media without K addition, averaging 496 mg. The average Ca accumulation was statistically the same in all other three dosages, averaging 341 mg and ranging from 312 to 368 mg.

In the mature compost medium, all K additions decreased Ca accumulation (Table 4.6). In the low proportion of compost, the decreases were by 43.6% in the dosage of 0.3 g K/kg media, by 47.6% in the dosage of 0.6 g K/kg media, and by 40.9% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 16.6% in the dosage of 0.3 g K/kg media, by 25.5% in the dosage of 0.6 g K/kg media, and by 9.2% in the dosage of 0.9 g K/kg media.

4.3.2.4.3 Analysis of Effects of the Immature Compost Medium

There was no significant difference between the regimes in the immature compost medium (Table 4.5). The average Ca accumulation was 362 mg in the high proportion of compost and 351 mg in the low proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.5). The average Ca accumulation was 357 mg, ranging from 334 to 380 mg.

In the immature compost medium, except for two dosages, all K additions increased Ca accumulation (Table 4.6). In the low proportion of compost, the Ca accumulation decreased by 2.5% in the dosage of 0.3 g K/kg media, and by 25.2% in the dosage of 0.9 g K/kg media. However, the Ca accumulation increased by 12.6% in the dosage of 0.6 g K/kg media. In the high proportion, the increases were by 13.6% in the dosage of 0.3 g K/kg media, by 6.1% in the dosage of 0.6 g K/kg media, and by 19.4% in the dosage of 0.9 g K/kg media.

4.3.2.5 Magnesium

4.3.2.5.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.4). The average Mg accumulation was 109 mg in the immature medium and 96 mg in the mature medium.

No significant difference existed between the regimes (Table 4.4). The average Mg accumulation was 105 mg in the low proportion of compost and 100 mg in the high proportion.

Some differences existed among the fertilization treatments (Table 4.4). The average Mg accumulation was the highest in the media without K addition, averaging 122 mg. The average Mg accumulation was statistically the same in all other three dosages, averaging 96 mg and ranging from 95 to 97 mg.

4.3.2.5.2 Analysis of Effects of the Mature Compost Medium

No significant difference existed between the regimes in the mature compost medium (Table 4.5). The average Mg accumulation was 97 mg in the high proportion of compost and 95 mg in the low proportion.

Some differences existed among the fertilization treatments in the mature compost medium (Table 4.5). The average Mg accumulation was the highest in the media without K addition, averaging 130 mg. The average Mg accumulation was statistically the same in all other three dosages, averaging 85 mg and ranging from 80 to 91 mg.

All K additions decreased Mg accumulation in the mature compost medium (Table 4.6). In the low proportion of compost, the decreases were by 47.9% in the dosage of 0.3 g K/kg media, by 46.5% in the dosage of 0.6 g K/kg media, and by 42.4% in the dosage of 0.9 g K/kg media. In the high proportion, the decreases were by 26.7% in the dosage of 0.3 g K/kg media, by 23.3% in the dosage of 0.6 g K/kg media, and by 14.7% in the dosage of 0.9 g K/kg media.

4.3.2.5.3 Analysis of Effects of the Immature Compost Medium

There was no significant difference between the regimes in the immature compost medium (Table 4.5). The average Mg accumulation was 115 mg per plant in the low proportion of compost and 103 mg in the high proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.5). The average Mg accumulation was 109 mg, ranging from 99 to 115 mg.

In the immature compost media, all K additions decreased Mg accumulation in the low proportion of compost (Table 4.6). The decreases were by 15.5% in the dosage of 0.3 g K/kg media, by 2.3% in the dosage of 0.6 g K/kg media, and by 27.1% in the dosage of 0.9 g K/kg media. However, in the high proportion of compost, the Mg accumulation decreased by 6.0% in the dosage of 0.6 g K/kg media. Otherwise the Mg accumulation increased by 11.0% in the dosage of 0.3 g K/kg media, and by 5.0% in the dosage of 0.9 g K/kg media.

4.3.2.6 Total Leaf Nutrient Accumulations vs. Total Plant Dry Weight

Unlike the previous two experiments (Chapter 2 and 3), there was no significant correlation between total leaf nutrient accumulation of each of five major plant nutrients and total plant weight.

4.3.3 Effect of Different Dosages of K on Soil Nutrient Residual Availability

Tables 4.7, 4.8, and 4.9 present information about the soil nutrient residual availability. Five nutrient elements were measured, including N, P, K, Ca, and Mg.

4.3.3.1 Nitrogen

4.3.3.1.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.7). The average residual available N was 67 mg/kg in the immature medium and 33 mg/kg in the mature medium.

A significant difference existed between the regimes (Table 4.7). The average residual available N was 67 mg/kg in the high proportion of compost and 34 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments (Table 4.7). The average residual available N was 51 mg/kg, ranging from 46 to 56 mg/kg.

4.3.3.1.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.8). The average residual available N was 39 mg/kg in the high proportion of compost and 28 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 4.8). The average residual available N was 33 mg/kg, ranging from 29 to 36 mg/kg.

In the mature compost medium, except for one dosage of K, all K additions increased soil N residual availability (Table 4.9). In the low proportion of compost, the increases were by 25.0% in the dosage of 0.3 g K/kg media, by 60.4% in the dosage of

0.6 g K/kg media, and by 46.2% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 13.2% in the dosage of 0.3 g K/kg media, and by 3.2% in the dosage of 0.6 g K/kg media. However, the soil N residual availability slightly decreased by 0.3% in the dosage of 0.9 g K/kg media.

4.3.3.1.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.8). The average residual available N was 95 mg/kg in the high proportion of compost and 40 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.8). The average residual available N was 67 mg/kg, ranging from 62 to 78 mg/kg.

Except for one dosage of K, all K additions increased soil N residual availability in the immature compost medium (Table 4.9). In the low proportion of compost, the soil N residual availability increased by 27.4% in the dosage of 0.3 g K/kg media, and by 16.3% in the dosage of 0.6 g K/kg media. However, the soil N residual availability slightly decreased by 1.4% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 23.8% in the dosage of 0.3 g K/kg media, by 3.7% in the dosage of 0.6 g K/kg media, and by 0.2% in the dosage of 0.9 g K/kg media.

4.3.3.2 Phosphorus

4.3.3.2.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.7). The average residual available P was 24 mg/kg in the mature medium and 22 mg/kg in the immature medium.

A significant difference existed between the regimes (Table 4.7). The average residual available P was 29 mg/kg in the high proportion of compost and 17 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments (Table 4.7). The average residual available P was 23 mg/kg, ranging from 22 to 24 mg/kg.

4.3.3.2.2 Analysis of Effects of the Mature Compost Media

A significant difference existed between the regimes in the mature compost medium (Table 4.8). The average residual available P was 30 mg/kg in the high proportion of compost and 18 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 4.8). The average residual available P was 24 mg/kg, ranging from 22 to 26 mg/kg.

In the mature compost media, all K additions decreased soil P residual availability in the low proportion of compost (Table 4.9). The decreases were by 12.6% in the dosage of 0.3 g K/kg media, by 4.7% in the dosage of 0.6 g K/kg media, and by 8.4% in the dosage of 0.9 g K/kg media. In the high proportion of the mature compost medium, however, all dosages increased soil P residual availability. The increases were by 16.3% in the dosage of 0.3 g K/kg media, by 24.0% in the dosage of 0.6 g K/kg media, and by 31.8% in the dosage of 0.9 g K/kg media.

4.3.3.2.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.8). The average residual available P was 28 mg/kg in the high proportion of compost and 15 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments in the immature compost medium (Table 4.8). The average residual available P was 22 mg/kg, ranging from 21 to 22 mg/kg.

In the immature compost media, all K additions decreased soil P residual availability in the low proportion of compost (Table 4.9). The decreases were by 7.3% in the dosage of 0.3 g K/kg media, by 14.6% in the dosage of 0.6 g K/kg media, and by 4.9% in the dosage of 0.9 g K/kg media. However, all the dosages increased soil P residual availability slightly in the high proportion (Table 4.9). The increases were by 1.5% in the dosage of 0.3 g K/kg, by 1.8% in the dosage of 0.6 g K/kg media, and by 5.8% in the dosage of 0.9 g K/kg media.

4.3.3.3 Potassium

4.3.3.3.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.7). The average residual available K was 238 mg/kg in the immature medium and 184 mg/kg in the mature medium.

A significant difference existed between the regimes (Table 4.7). The average residual available K was 249 mg/kg in the high proportion of compost and 173 mg/kg in the low proportion.

Significant differences existed among the fertilization treatments (Table 4.7). Generally speaking, residual available K increased as the K supply increased in the media. The average amounts of residual available K were 394 mg/kg in the dosage of 0.9 g K/kg media, 254 mg/kg in the dosage of 0.6 g K/kg media, 136 mg/kg in the dosage of 0.3 g K/kg medial, and 60 mg/kg in the no K added media.

4.3.3.3.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.8). The average residual available K was 207 mg/kg in the high proportion of compost and 161 mg/kg in the low proportion.

Significant differences existed among the fertilization treatments in the mature compost medium (Table 4.8). The average residual available K was 44 mg/kg in the media without K addition, 106 mg/kg in the dosage of 0.3 g K/kg media, 233 mg/kg in the dosage of 0.6 g K/kg media, and 353 mg/kg in the dosage of 0.9 g K/kg media. The more K added, the higher the residual available K.

All K additions increased soil K residual availability in the mature compost medium (Table 4.9). In the low proportion of compost, the increases were by 159% in the dosage of 0.3 g K/kg media, by 531% in the dosage of 0.6 g K/kg media, and by 828% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 126% in the dosage of 0.3 g K/kg media, by 358% in the dosage of 0.6 g K/kg media, and by 614% in the dosage of 0.9 g K/kg media.

4.3.3.3.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.8). The average residual available K was 291 mg/kg in the high proportion of compost and 184 mg/kg in the low proportion.

Significant differences existed among the fertilization treatments in the immature compost medium (Table 4.8). The average residual available K was 75 mg/kg in the no K added media, 166 mg/kg in the dosage of 0.3 g K/kg media, 276 mg/kg in the dosage of 0.6 g K/kg media, and 435 mg/kg in the dosage of 0.9 g K/kg media.

In the immature compost medium, all K additions increased soil K residual availability (Table 4.9). In the low proportion of compost, the increases were by 247% in the dosage of 0.3 g K/kg media, by 557% in the dosage of 0.6 g K/kg media, and by 915% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 81.5% in the dosage of 0.3 g K/kg media, by 178% in the dosage of 0.6 g K/kg media, and by 346% in the dosage of 0.9 g K/kg media.

4.3.3.4 Calcium

4.3.3.4.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.7). The average residual available Ca was 115 mg/kg in the mature medium and 96 mg/kg in the immature medium.

There was a significant difference between the regimes (Table 4.7). The average residual available Ca was 121 mg/kg in the high proportion of compost and 90 mg/kg in the low proportion.

Some significant differences existed among the fertilization treatments (Table 4.7). The average residual available Ca was the highest in the dosage of 0.9 g K/kg media, averaging 114 mg/kg. All other dosages statistically had the same amount of residual available Ca, averaging 103 mg/kg and ranging from 100 to 106 mg/kg.

4.3.3.4.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.8). The average residual available Ca was 135 mg/kg in the high proportion of compost and 95 mg/kg in the low proportion.

Some significant differences existed among the fertilization treatments in the mature compost medium (Table 4.8). The average residual available Ca was the highest in the dosage of 0.9 g K/kg media, averaging 128 mg/kg. The average residual available Ca was the least in the media without K addition, averaging 104 mg/kg. The average residual available Ca was 111 mg/kg in the dosage of 0.3 g K/kg media. The average residual available Ca was 117 mg/kg in the dosage of 0.6 g K/kg media.

In the mature compost medium, all K addition increased soil Ca residual availability (Table 4.9). In the low proportion of compost, the increases were by 3.7% in the dosage of 0.3 g K/kg media, by 12.9% in the dosage of 0.6 g K/kg media, and by 18.3% in the dosage of 0.9 g K/kg media. In the high proportion, the increases were by 8.8% in the dosage of 0.3 g K/kg media, by 11.0% in the dosage of 0.6 g K/kg media, and by 25.4% in the dosage of 0.9 g K/kg media.

4.3.3.4.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.8). The average residual available Ca was 107 mg/kg in the high proportion of compost and 85 mg/kg in the low proportion.

Some significant differences existed among the fertilization treatments in the immature compost medium (Table 4.8). The average residual available Ca was the highest in the dosage of 0.9 g K/kg media, averaging 99 mg/kg. The average residual available Ca was the least in the dosage of 0.3 g K/kg media, averaging 93 mg/kg. The average residual available Ca was statistically the same in the no K added media, averaging 96 mg/kg.

In the immature compost medium, all K additions increased soil Ca residual availability in the low proportion of compost (Table 4.9). The increases were by 1.7% in the dosage of 0.3 g K/kg media, by 7.0% in the dosage of 0.6 g K/kg media, and by 8.6% in the dosage of 0.9 g K/kg media. However, all K additions decreased soil Ca residual availability in the high proportion. The decreases were by 7.3% in the dosage of 0.3 g K/kg media, by 8.6% in the dosage of 0.6 g K/kg media, and by 1.4% in the dosage of 0.9 g K/kg media.

4.3.3.5 Magnesium

4.3.3.5.1 Analysis of Overall Effects of the Two Compost Media

There was a significant difference between the mature and immature media (Table 4.7). The average residual available Mg was 11.3 mg/kg in the immature medium and 8.6 mg/kg in the mature medium.

There was a significant difference between the regimes (Table 4.7). The average residual available Mg was 11.3 mg/kg in the high proportion of compost and 8.5 mg/kg in the low proportion.

Some differences existed among the fertilization treatments (Table 4.7). The residual available Mg was the highest in the dosage of 0.9 g K/kg media, averaging 10.4 mg/kg. The residual available Mg was the least in the dosage of 0.6 g K/kg media, averaging 9.6 mg/kg. The residual available Mg was statistically the same in the no K added media, averaging 9.9 mg/kg.

4.3.3.5.2 Analysis of Effects of the Mature Compost Medium

There was a significant difference between the regimes in the mature compost medium (Table 4.8). The average residual available Mg was 9.2 mg/kg in the high proportion of compost and 8.0 mg/kg in the low proportion.

No significant differences existed among the fertilization treatments in the mature compost medium (Table 4.8). The average residual available Mg was 8.6 mg/kg, ranging from 8.3 to 8.9 mg/kg.

In the mature compost media, all K additions decreased soil Mg residual availability in the low proportion of compost (Table 4.9). The decreases were by 1.2% in the dosage of 0.3 g K/kg media, by 2.5% in the dosage of 0.6 g K/kg media, and by 3.7% in the dosage of 0.9 g K/kg media. In the high proportion, each K level behaved differently. The soil Mg residual availability decreased by 4.4% in the dosage of 0.3 g K/kg media, maintained the same soil Mg residual availability in the dosage of 0.6 g K/kg media, and increased soil Mg residual availability by 11.1% in the dosage of 0.9 g K/kg media (Table 4.9).

4.3.3.5.3 Analysis of Effects of the Immature Compost Medium

There was a significant difference between the regimes in the immature compost medium (Table 4.8). The average residual available Mg was 13.5 mg/kg in the high proportion of compost and 9.1 mg/kg in the low proportion.

Some differences existed among the fertilization treatments in the immature compost medium (Table 4.8). The residual available Mg was the highest in the dosage of 0.9 g K/kg media, averaging 11.8 mg/kg. The residual available Mg was the least in the dosage of 0.6 g K/kg media, averaging 10.7 mg/kg. The average residual available Mg was 11.4 mg/kg in the no K added and 0.3 g K/kg media.

In the immature compost media, all K additions increased soil Mg residual availability in the low proportion of compost (Table 4.9). The increases were by 3.5% apiece in the dosages of 0.3 and 0.6 g K/kg media, and by 9.2% in the dosage of 0.9 g K/kg media. However, all K additions decreased soil Mg residual availability in the high proportion (Table 4.9). The decreases were by 7.0% in the dosage of 0.3 g K/kg media, by 13.3% in the dosage of 0.6 g K/kg media, and by 1.4% in the dosage of 0.9 g K/kg media.

4.4 Discussion

4.4.1 Effects of Different Dosages of K on Plant Growth

Overall, the mature compost medium showed the better results than the immature compost medium regarding plant growth. They statistically produced the same results for numbers of flower, leaf, and stem fresh weight. The immature medium statistically gave better results in leaf fresh and dry weight than the mature medium.

In general, regimes did not make much difference in promoting plant growth. The better results from the higher proportion of compost used, if any, might be attributed to the higher content of nutrients in the higher proportion of compost added.

Overall, there was not much difference among the fertilization treatments. Some of growth indices, such as numbers of flower, fruit fresh and dry weights were statistically improved by fertilization with K.

When the mature compost was used, there were no statistical differences between the low and high proportion of compost regarding most growth indices except the high proportion of compost yielded better results for leaf fresh and dry weights. This result could be attributed to the nutrients in the compost. The more compost was used, the more nutrients were provided.

Fertilization with different dosages of K in the mature medium statistically increased fruit fresh and dry weight. The fertilization made no significant differences on plant height, numbers of flower and fruit, and total dry weight. The fertilization did not enhance numbers of leaf, leaf fresh and dry weights, stem fresh and dry weights.

When the immature compost was used, generally speaking, there was no significant difference between the two regimes even though the low proportion of compost was better for plant height and the high proportion was better for leaf fresh weight.

Fertilization with different dosages of K statistically increased numbers of flower, stem fresh and dry weights, and total dry weight in the immature medium. The fertilization statistically generated the same results for all other growth indices. However, the treatments with K addition generally created the higher values, and the dosage of 0.6 g K/kg media usually gave better results than the other K dosages.

Unlike those discovered in the previous experiments, there were no statistically correlated relationships between each of most various growth indices and total plant dry weight except that there was a significantly highly correlated relationship between stem dry weight and total dry weight.

4.4.2 Effects of Different Dosages of K on Leaf Nutrient Accumulations

There were no significantly correlated relationships between each of the major nutrient accumulations in plant leaves and total plant dry weight.

When the mature compost was used, the average nutrient accumulations were usually higher in the high proportion of compost because the larger quantity of compost could provide more nutrients for plant growth.

When the immature compost was used, the average nutrient accumulations were usually higher in the high proportion of compost because the larger quantity of compost could provide more nutrients for plant growth.

As those situations in the mature medium, fertilization with different dosages of K in the immature medium commonly made no significant differences on nutrient accumulations except that the treatments with K addition greatly increased K accumulations in plant leaves. The results could be attributed to the fact that high content of NH_4 was added purposely. The addition of K relieved the damages caused by the high content of NH_4. The addition of K would reduce the absorption of NH_4 through antagonism, which resulted in a good balance among the plant nutrients, greatly relieved plants from the stress and maintained other nutrient accumulations at certain level.

4.4.3 Effects of Different Dosages of K on Soil Nutrient Residual Availability

In the mature medium, the high proportion of compost had higher contents of all five major nutrients including N, P, K, Ca and Mg than the low proportion of compost. The higher residual availability of all five nutrients might be attributed to the higher amount of those nutrients in the higher proportion of compost.

In the mature medium, the treatments with K addition greatly increased the soil K and Ca residual availability. The high residual availability of soil K could be attributed to the application of K. The high residual availability of soil Ca could be attributed to the presumption that the high concentration of K could exchange Ca from its binding sites on soil surfaces and release it into soil solution. Or massive K due to the application in the soil medium would compete with Ca, which resulted in less absorption of Ca by plants and more Ca left in the soil medium.

In the immature medium, the high proportion of compost had higher contents of all five major nutrients including N, P, K, Ca and Mg than the low proportion. The higher residual availability of all five nutrients might be attributed to the higher amount of those nutrients in the higher proportion of compost.

In the immature medium, the treatments with K addition greatly increased the soil K, Ca, and Mg residual availability. The high residual availability of soil K could be attributed to the large amount application with K. The high residual availability of soil Ca and Mg could be also attributed to the presumption that the high concentration of K could exchange Ca and Mg from their binding sites on soil surfaces and release them into soil solution. Or massive K due to the application in the soil medium would compete with Ca, which resulted in less absorption of Ca by plants and more Ca left in the soil medium.

Table 4.1 Comparison of Overall Averages of Growth Indices for 3rd Experiment

Index	Variables							
	Composts		Regimes		Fertilization (g/kg)			
	Mature	Immature	Low	High	0.0	0.3	0.6	0.9
Height (cm)	95a	88b	92a	90a	87a	91a	94a	93a
No. of Flower	51a	52a	50a	53a	45b	49ab	60a	52ab
No. of Fruit	4.9a	3.4b	4.2a	4.1a	3.1a	4.1a	4.7a	4.8a
Fruit FW (g)	105a	38b	83a	60a	38b	70ab	100a	77ab
Fruit DW (g)	7.9a	3.4b	6.4a	4.9a	3.1b	5.7ab	7.3a	6.4ab
No. of Leaf	35a	35a	34a	36a	35a	35a	34a	35a
Leaf FW (g)	136b	163a	139b	160a	153a	143a	147a	155a
Leaf DW (g)	16.5b	18.5a	16.5b	18.5a	17.8a	16.9a	17.3a	17.9a
Stem FW (g)	78a	72a	75a	75a	79a	74a	73a	73a
Stem DW (g)	11.5a	9.0b	10.4a	10.1a	11.1a	10.3a	10.0a	9.5a
Total DW (g)	35.8a	30.9b	33.2a	33.5a	32.0a	33.0a	34.6a	33.8a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).
FW= Fresh Weight; and DW= Dry Weight.

Table 4.2 Comparison of Growth Index Averages for Mature and Immature Composts in 3rd Experiment

Index	Mature Compost						Immature Compost					
	Regime		Fertilization (g/kg)				Regime		Fertilization (g/kg)			
	Low	High	0.0	0.3	0.6	0.9	Low	High	0.0	0.3	0.6	0.9
Height (cm)	93a	97a	90a	94a	99a	96a	91a	84b	84a	88a	89a	90a
No. of Flower	49a	53a	46a	48a	59a	51a	51a	53a	44b	49ab	60a	54ab
No. of Fruit	5.0a	4.8a	3.6a	5.0a	5.8a	5.3a	3.4a	3.4a	2.6a	3.3a	3.6a	4.3a
Fruit FW (g)	119a	91a	51b	102ab	165a	102ab	47a	29a	25a	39a	36a	53a
Fruit DW (g)	8.8a	7.0a	3.9b	7.9ab	11.6a	8.0ab	3.9a	2.8a	2.3a	3.5a	3.0a	4.8a
No. of Leaf	34a	36a	38a	36ab	32b	34ab	34a	36a	32a	34a	37a	36a
Leaf FW (g)	126b	145a	160a	122b	121b	138ab	152b	174a	146a	164a	172a	171a
Leaf DW (g)	15.4b	17.5a	19.3a	15.2b	14.3b	17.0ab	17.6a	19.4a	16.3a	18.7a	20.3a	18.8a
Stem FW (g)	74a	81a	95a	76ab	66b	74b	76a	69a	63b	73ab	81a	72ab
Stem DW (g)	11.3a	11.7a	14.6a	11.3b	9.6b	10.4b	9.5a	8.5a	7.6b	9.3ab	10.4a	8.7ab
Total DW (g)	35.4a	36.2a	37.8a	34.4a	35.5a	35.4a	31.1a	30.7a	26.2b	31.5ab	33.7a	32.2ab

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).
FW= Fresh Weight; DW= Dry Weight.

Table 4.3 3rd Experiment Growth Index Averages for A: Mature Compost, B: Immature Compost

A: Mature Compost

		Index										
Regime	Fertilizer	Height	Flower	Fruit			Leaf			Stem		
	K_2O/kg		#	#	FW	DW	#	FW	DW	FW	DW	TDW
	g	cm			g	g		g	g	g	g	g
L	0.0	87	39	3.5	35	3.1	39	159	20	102	16	39
	0.3	91	38	6.3	133	10.4	32	109	14	63	9.9	35
	0.6	99	64	4.5	206	13.9	30	108	13	58	8.7	35
	0.9	96	55	5.8	100	7.7	34	128	15	73	10.7	33
H	0.0	94	54	3.8	66	4.8	37	162	19	89	13.3	37
	0.3	97	59	3.8	71	5.5	40	135	16	88	12.7	34
	0.6	100	55	7.0	123	9.4	33	134	16	74	10.5	36
	0.9	95	46	4.8	105	8.4	34	149	19	75	10.2	38

Abbreviations: L= low proportion of compost; H= high proportion of compost; FW= Fresh Weight; DW= Dry Weight, and TDW= Total Dry Weight.

Continued next page.

B: Immature Compost

		Index										
Regime	Fertilizer	Height	Flower	Fruit			Leaf			Stem		
	K_2O/kg		#	#	FW	DW	#	FW	DW	FW	DW	TDW
	g	cm			--------g-------			----------------------------g----------------------				
L	0.0	90	48	2.8	31	2.8	33	147	16	72	8.5	28
	0.3	90	48	2.0	42	3.6	32	144	16	75	9.3	29
	0.6	90	61	4.5	54	4.4	36	166	21	84	11.5	37
	0.9	93	49	4.5	60	5.0	34	154	17	72	8.7	31
H	0.0	78	40	2.5	19	1.7	32	145	16	54	6.7	25
	0.3	87	50	4.5	35	3.4	37	184	21	72	9.3	34
	0.6	87	60	2.8	18	1.7	38	178	20	77	9.3	31
	0.9	87	60	4.0	45	4.5	37	189	21	73	8.6	34

Abbreviations: L= low proportion of compost; H= high proportion of compost; FW= Fresh Weight; DW= Dry Weight, and TDW= Total Dry Weight.

Table 4.4 Overall Comparison of Leaf Nutrient Accumulations for 3rd Experiment

	Variables							
Element	Composts		Regimes		Fertilization (g/kg)			
(mg)	Mature	Immature	Low	High	0.0	0.3	0.6	0.9
N	458b	730a	524b	664a	580a	563a	611a	621a
P	63a	67a	56b	75a	66a	64a	63a	68a
K	491b	569a	518a	542a	361c	502b	590ab	667a
Ca	380a	357a	350b	386a	421a	355b	346b	351b
Mg	96b	109a	105a	100a	122a	95b	97b	95b

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 4.5. Comparison of Leaf Nutrient Accumulations for Mature and Immature Composts in 3rd Experiment

Elements	Mature Compost						Immature Compost					
	Regime		Fertilization (g/kg)				Regime		Fertilization (g/kg)			
(mg)	Low	High	0.0	0.3	0.6	0.9	Low	High	0.0	0.3	0.6	0.9
N	400b	515a	507a	409b	418b	497ab	648b	813a	654a	718a	805a	746a
P	53b	73a	71a	62a	54a	66a	58b	77a	61a	67a	71a	71a
K	469a	514a	447b	461ab	456ab	602a	567a	571a	275c	544b	724a	732a
Ca	349b	410a	496a	344b	312b	368b	351a	362a	347a	366a	380a	334a
Mg	95a	97a	130a	80b	83b	91b	115a	103a	115a	110a	110a	99a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 4.6 3rd Experiment Leaf Nutrient Concentration (%)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg	Leaf DW
Mature	L	0	2.52	0.33	2.77	2.64	0.73	20 g
		0.3	2.39	0.39	2.61	2.06	0.53	14 g
		0.6	2.76	0.32	2.73	2.12	0.63	13 g
		0.9	2.83	0.34	4.08	2.11	0.57	15 g
	H	0	2.73	0.41	1.82	2.48	0.62	19 g
		0.3	2.93	0.42	3.34	2.42	0.53	16 g
		0.6	3.09	0.42	3.52	2.26	0.56	16 g
		0.9	3.04	0.43	3.14	2.25	0.52	19 g
Immature	L	0	3.54	0.33	1.42	2.21	0.78	16 g
		0.3	3.70	0.34	3.37	2.19	0.67	16 g
		0.6	3.75	0.31	3.63	1.95	0.60	21 g
		0.9	3.73	0.36	4.33	1.67	0.58	17 g
	H	0	4.47	0.41	1.98	2.04	0.62	16 g
		0.3	3.96	0.38	2.56	1.80	0.53	21 g
		0.6	4.19	0.40	3.54	1.81	0.48	20 g
		0.9	4.18	0.40	3.56	1.89	0.50	21 g

L= low proportion of compost; H= high proportion of compost; DW= Dry Weight.

Table 4.7 3rd Experiment Leaf Nutrient Accumulations (mg)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg
Mature	L	0	498	66	547	521	144
		0.3	341	55	374	294	75
		0.6	349	42	353	273	77
		0.9	414	50	601	308	83
	H	0	516	77	347	470	116
		0.3	477	68	547	392	85
		0.6	487	66	559	350	89
		0.9	579	82	603	427	99
Immature	L	0	583	55	232	365	129
		0.3	601	54	550	356	109
		0.6	788	65	760	411	126
		0.9	620	59	727	273	94
	H	0	724	66	319	330	100
		0.3	834	79	538	375	111
		0.6	822	78	689	350	94
		0.9	873	83	737	394	105

L= low proportion of compost; H= high proportion of compost.

Table 4.8 Overall Comparison of Soil Residual Available Nutrients Content for 3rd Experiment

Element	Variables							
	Composts		Regimes		Fertilization (g/kg)			
(mg/kg)	Mature	Immature	Low	High	0.0	0.3	0.6	0.9
N	33b	67a	34b	67a	46a	56a	52a	48a
P	24a	22b	17b	29a	22a	23a	23a	24a
K	184b	238a	173b	249a	60d	136c	254b	394a
Ca	115a	96b	90b	121a	100b	102b	106b	114a
Mg	8.6b	11.3a	8.5b	11.3a	10.1ab	9.7ab	9.6b	10.4a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 4.9 Comparison of Soil Residual Available Nutrient Contents for Mature and Immature Composts in 3rd Experiment

Elements	Mature Compost						Immature Compost					
	Regime		Fertilization (g/kg)				Regime		Fertilization (g/kg)			
(ppm)	Low	High	0.0	0.3	0.6	0.9	Low	High	0.0	0.3	0.6	0.9
N	28b	39a	29a	34a	36a	34a	40b	95a	62a	78a	67a	62a
P	18b	30a	22a	23a	25a	26a	15b	28a	22a	22a	21a	22a
K	161b	207a	44d	106c	233b	353a	184b	291a	75d	166c	276b	435a
Ca	95b	135a	104c	111bc	117ab	128a	85b	107a	97ab	93b	95ab	99a
Mg	8.0b	9.2a	8.6a	8.3a	8.5a	8.9a	9.1b	13.5a	11.5ab	11.2ab	10.7b	11.8a

Within rows and under same variables, means followed by different letters are significantly different by LSD ($P \leq 0.05$).

Table 4.10 Soil Residual Available Nutrient Contents for 3rd Experiment (mg/kg)

Compost	Regime	Fertilizer	N	P	K	Ca	Mg
Mature	L	0	21	19	34	88	8.1
		0.3	27	17	87	91	8.0
		0.6	34	18	212	99	7.9
		0.9	31	17	312	104	7.8
	H	0	37	26	55	121	9.0
		0.3	42	30	125	132	8.6
		0.6	38	32	253	134	9.0
		0.9	37	34	395	152	10.0
Immature	L	0	36	16	35	82	8.7
		0.3	46	15	121	83	9.0
		0.6	42	14	229	87	9.0
		0.9	36	16	353	89	9.5
	H	0	89	28	116	112	14.3
		0.3	110	28	210	103	13.3
		0.6	92	28	323	102	12.4
		0.9	89	29	517	110	14.1

L= low proportion of compost; H= high proportion of compost.

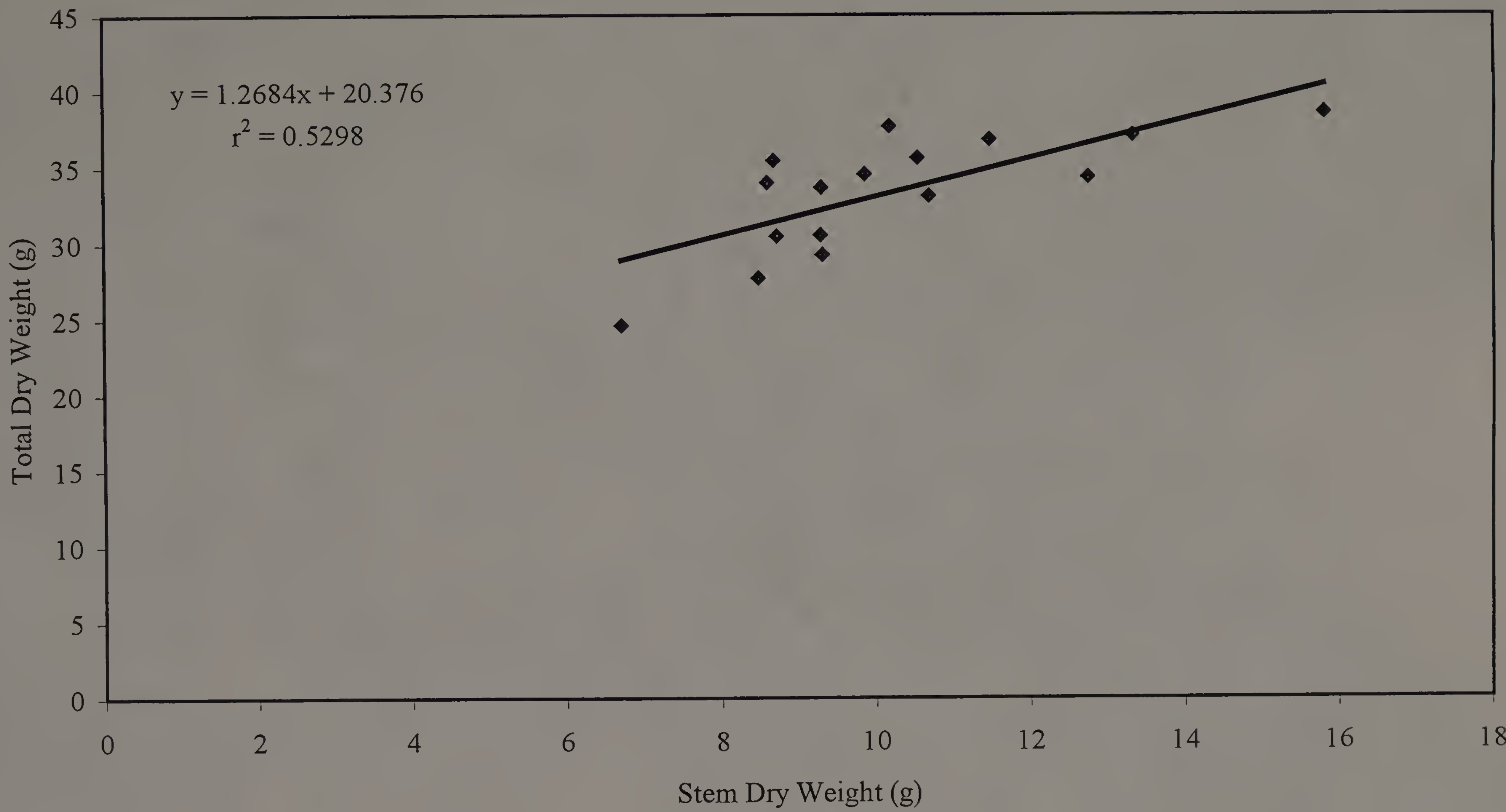


Figure 4.1 Relationship between Stem Dry Weight and Total Dry Weight for 3rd Experiment

BIBLIOGRAPHY

Ahrens, E., and G. Farkasdy. 1969. Investigation on nitrogen mineralization in soil after application of town refuse of different degrees of decomposition. Sonderh. Landw. Forsch. 23: 77-78.

Airan, D.S., and J.H. Bell. 1980. Resource recovery through composting-a sleeping giant. p.121-129. In proc. 1980 Natl. Waste Process. Conf., Washington, DC. 11-14 May 1980. Am. Soc. Mech. Eng., New York, NY.

Anderson, A.. 1983. Composted municipal refuse as fertilizer and soil conditioner. Effects on the contents of heavy metals in soil and plant, as compared to sewage sludge, manure and commercial fertilizers. p. 146-156. In S. Berglund et al. (ed.) Utilization of sewage sludge on land: Rates of application and long-term effects of metals. D. Reidel Publishing Company, Boston, MA.

Arkin, G., and H. Taylor. 1981. Modifying the root environment to reduce crop stress Monograph #4. American Society of Agricultural Engineers. St. Joseph, MI.

Ashley, R.A. 1993. Tomato response to two compost products. Grower. Satorrs, Conn.: Cooperative Extension Services, US Department of Agriculture, College of Agriculture and Natural Resources, The University of Connecticut, 93 (5): 6-7.

Avnimelech, T., A. Cohen, and D. Shkedi. 1990. The effect of municipal solid waste compost on the fertility of clay soils. Soil Technology, 3:275-282.

Baca, M. T., I. C. Delgado, M. De-Nobili, E. Estaban, A. J. Sanchez-Raya.1995. Influence of compost maturity on nutrient status of sunflowers. Comm. Soil Sci. Plant Anal. New York, N.Y. 26:169-181.

Barker, A. V., 1967. Growth and nitrogen distribution patterns in bean (Phaseolus vulgaris L.) plants subjected to ammonium nutrition: II. Effects of potassium in a calcium carbonate buffered system. Advancing Fronteirs of Plant Sciences 18:7-22.

Barker, A. V., 1976. Using tomato plants to assess the release of potassium from fertilizers. J. Agronomic Education, 5(11):63-65.

Barker, A. V., and W. H. Lachman. 1986. Potassium and ammonium interactions in nutrition of tomato cultivars and mutants. J. Plant Nutrition, 9(1):1-21.

Barker A. V., D.N. Maynard, and W. H. Lachman. 1967. Induction of tomato stem and leaf lesions, and potassium deficiency, by excessive ammonium nutrition. Soil Sci. 103:319-327

Barker, A. V., and K. M. Ready. 1994. Ethylene evolution by tomatoes stressed by Ammonium nutrition. J. Amer. Soc. Hort. Sci., 119(4):706-710.

Barker, A.V., R. J. Volk, and W. A. Jackson. 1966. Growth and nitrogen nitrogen distribution patterns in bean (Phaseolus vulgaris L.) plants subjected to ammonium nutrition: I. Effects of carbonates and acidity control. Soil Science Society of America Proceedings 30:228-232.

Barriuso, E., S. Houot, and C. Serrawittling. 1997. Influence of compost addition to soil on the behavior of herbicides. Pesticide Science, 49(1):65-75.

Bengston, G.W., and J.J. Cornette. 1973. Disposal of composted municipal waste in a lantation of young slash pine: Effects on soil and trees. J. Environ. Qual. 2:441-444.

Berner, A., D. Scherrer, and U. Niggli. 1995. Effect of different organic manures and garden waste compost on the nitrate dynamics in soil, N uptake and yield of winter wheat. Biol. Agric. Hortic. 11 (1/4):289-300.

Blanco, M. J. 1994. Maturity assessment of wheat straw composts by thermogravimetric analysis. J-agric-food-chem. Washington D.C. American Chemical Society. 42:2454-2459.

Bradstreet, R. B. 1965. The Kjeldahl Method for Organic Nitrogen. Academic Press, New York, NY.

Brietenbeck, G., W. Hallmark. 1993. Compost mulch affects rhizosphere temperatures in winter sugarcane stubble. La. Agric. La. Agric. Exp. Stn. 36 (1) 22-23.

Brodie, H. L., F. R. Gouin, and L. E. Carr. 1994. What makes Good Compost? Biocycle, 35 (7):66-68.

Buchana, M., and S.R. Gliessman. 1991. How compost fertilization affects soil nitrogen and crop yield. BioCycle. 32 (12): 72-77.

Buhr, A. R., T. McClure, D. C. Slivka, and R. Albrech. 1993. Compost supply and demand. Biocycle, 34(1):54-58.

Canarutto, S., G. Petruzzelli, L. Lubrano, and G. Guidi. 1991. How composting affects heavy metal content. BioCycle 32(6): 48-50.

Carlsb(k M. and U. Rech. 1996. Application of compost in amenity areas. Management of Urban Biodegradable Waste. James & James (Science Publishers) Ltd., London. Chandrasekaran, S. and T. Yoshida. 1973. Effect of organic acid transformations in submerged soils on rice plant. Soil Sci. Plant Nutrition, 19:39-45.

Chanyasak, V., A. Katayama, M. F. Hirai, S. Mori, and H. Kubota. 1983. Effects of compost maturity on growth of Komatsuna (*Brassica rapa* var. pervidis) in Neubauer's pot. Soil Sci. and Plant Nutrition, 29(3): 239-250.

Chanyasak, V., A. Katayama, M. F. Hirai, S. Mori, and H. Kubota. 1983. Effects of compost maturity on growth of Komatsuna (*Brassica rapa* var. pervidis) in Neubauer's pot. Soil Sci. and Plant Nutrition, 29(3): 251-259.

Cisar, J.L., and G.H. Snyder. 1992. Sod production on a solid-waste compost over plastic. HortScience. 27 (3):219-222.

Cole, M.A., L. Zhang, and X. Liu. 1995. Remediation of pesticide contaminated soil by planting and compost addition. Compost sci. util. 3 (4): 20-30.

Corey, K. A., and A. V. Barker. 1989. Ethylene evolution and polyamine accumulation By tomato subjected to interactive stresses of ammonium toxicity and potassium deficiency. J. Amer. Soc. Hort. Sci., 114(4):651-655.

De Bertholdi, M., M. Civilini and G. Comi. 1990. MSW standards in the European Community. Biocycle, 31(8):60-62.

De Haan, S. 1981. Results of municipal waste compost research over more than fifty years at the Institute for Soil Fertility at Harent Groningen, the Netherlands. Neth. J. Agric. Sci. 29: 49-61.

Devos, J. A. 1996. Testing compost as an anti-wind erosion agent in a wind tunnel. Soil Technology, 9(4):209-221.

Diaz-Ravina, M., M.J. Acea, and T. Carballas. 1989. Microbiological characterization of four composted urban refuses. Biological Wastes 30: 89-100.

Diez, J.A. et. al. 1995. Control of nitrate pollution by application of controlled release fertilizer (CRF), compost and an optimized irrigation system. Fertil. Res. 43 (1/3):191-195.

Elnadi A.H. et. al. 1995. Chemical, physico-chemical and microbiological examination of town refuse compost and chicken manure as organic fertilizers. J. Arid Environ. 30 (1):107-113.

Erhart, E. and K. Burian. 1997. Evaluation quality and suppressiveness of Austrian biowaste composts. Compost Science & Utilization, 5(3):15-24.

Feng, J., and A. V., Barker. 1992. Ethylene evolution and ammonium accumulation by nutrient-stressed tomato plants. J. Plant Nutrition, 15(2):137-153.

Findenegg, G. R. A. 1987. Comparative study of ammonium toxicity at different constant pH of the nutrient solution. Plant and Soil, 103:239-243.

Finstein, Ms.S., and F.C. Miller. 1985. Principles of composting leading to maximization of decomposition rate, odor control, and cost effectiveness. p. 13-26. In J.K.R. Gasser (ed.) Composting of agricultural and other wastes. Elsevier Applied Science Publisher, New York.

Forste, J. B. 1996. Federal regulatory requirements. Biosolids Treatment and Management. Edited by Mark J. Girovich. Marcel Dekker, Inc.

Fricke K., and H. Vogtmann. 1994. Compost Quality-physical characteristics, nutrient content, heavy metals and organic chemicals. Toxicological & Environmental Chemistry. 43 (1-2): 95-114.

Gamliel, A., and J.J. Stapleton. 1993. Effect of chicken compost or ammonium phosphate and solarization on pathogen control, rhizosphere microorganisms, and lettuce growth. 77 (9): 886-891.

Garcia, C., T. Hernandez, F. Costa, and M. Ayuso. 1992. Evaluation of the maturity of municipal waste compost using simple chemical parameters. Comm. Soil Sci. Plant Anal. New York, N.Y. 23:1501-1512.

Garland, G.A., T.A. Grist, R.E. Green. 1995. The compost story: from soil enrichment to pollution remediation. Biocycle. 36 (10): 53-56.

Giusquiani, P.L., et. al. 1995. Urban waste compost: effects on physical, chemical, and biochemical soil properties. J. Environ. Qual. 24 (1): 175-182.

Glenn, J., and D. Riggle. 1991. The state of garbage in America. BioCycle 31(4): 34-38.

Godden, B., M. Mareschal, X. Vekemans, and M. Penninckx. 1987. Effects of manure compost on soil microbiological properties. p. 473-478. In M. De Bertoldi et al. (ed.) Compost: Production, quality, and use. Elsevier Applied Science Publisher, London.

Goldstein, N. 1989a. Solid waste composting in the U.S. BioCycle 30(4): 32-37.

Gouin, F. R. 1993. Utilization of sewage sludge compost in horticulture. Alexandria, VA: American Society for Horticultural Science. 3 (2): 161-163.

Griffiths, B. S. 1989. Enhanced nitrification in the presence of bacteriophagous protozoa. Soil Biology and Biochemistry, 21(8):1045-1051.

Hadar, Y., R. Madelbaum, and B. Gorodecki. 1992. Biological control of soilborne plant pathogens by suppressive compost. NATO ASI Ser. Ser. A Life Sci. 230: 79-83.

He, X.T., T.J. Logan, and S.J. Train. 1995. Physical and chemical characteristics of selected U.S. municipal solid waste composts. J. Environ. Qual. 24(3): 543-552.

He, X-T, S. J. Traina, and T. J. Logan. 1992. Chemical Properties of Municipal Solid Waste Composts. J. Environ. Qual., 21:318-329.

Henry G., and D. Bush. 1996. Applying yard trimmings compost to Florida highways. Biocycle. 37 (2): 53-54.

Hernando, S., M.C. Lobo, and A. Polo. 1989. Effect of the application of a municipal refuse compost on the physical and chemical properties of a soil. Sci. Total Environ. 82: 589-596.

Hoitink, H. A. J., and M. E. Grebus. 1994. Plant disease control. Composting Source Separated Organics. J. G. Press. Emmaus, Penn. Hoitink, H., M. Boehm, and Y. Hadar. 1993. Mechanisms of suppression of soilborne plant pathogens in compost-amended substrate. Science and Engineering of Compost. Renaissance Publications. Worthington, OH.

Hoitink, H.A.J., Y. Inbar, and M.J.Boehm. 1993. Compost can suppress soil-borne diseases in container media. Am. Nurserym. 178 (6):91-94.

Hornick, S. 1984. Utilization of sewage sludge compost as a soil conditioner and Fertilizer for plant growth. Agriculture Information Bulletin #464. USDA, Agricultural Research Service. Beltsville, MD.

Hountin, J.A. et. al. 1995. Effect of peat moss-shrimp wastes composts on the growth of barley (Hordeum vulgare L.) on a loamy sand soil. Comm. Soil Sci. Plant Anal. 26 (19/20): 3275-3289.

Hu, Y., and A. V. Barker. 1999. A Single Plant Tissue Digestion for Macronutrient Analysis. Comm. Soil Sci. Plant Anal., 30(5&6), 677-687.

Inbar, Y., Y. Chen, Y. Hadar, and H. A. J. Hoitink. 1990. New approaches to compost maturity. Biocycle, 31(12):64-69.

Kapetanios, E.G., and M. Loizidou. 1992. Heavy metal removal by zeolite in tomato cultivation using compost. Acta. Hortic. 302:63-71.

Keeling, A. A., B. S. Griffths, K. Ritz, and M. Myers. 1995. Effects of compost stability on plant growth, microbiological parameters and nitrogen availability in media containing mixed garden-waste compost. Bioresour-technol. Oxford, U.K. Elsevier Science Limited. 54:279-284.

Keeling, A.A. et. al. 1995. Effects of compost stability on plant growth, microbiological parameters and nitrogen availability in media containing mixed garden-waste compost. Bioresour. technol. Oxford, UK: Elsevier Science Limited.

Kim, KD., S. Nemec, and G. Musson. 1997. Effects of composts and soil amendments on soil microflora and phytophthora root and crown rot of bell pepper. Crop Protection, 16(2):165-172.

Kuter, G. A., E. B. Nelson, H. A. J. Hoitink, and L. V. Madden. 1983. Fungal populations in container media amended with composted hardwood bark suppressive and conducive to rhizoctonia damping-off. Phytopathology, 73(10):1450-1456.

Lamanna, D., M. Castelnuovo, and G. D'Angelo. 1991. Compost-based media as alternative to peat on ten pot ornamentals. Acta. Hortic. 294: 125-129.

Lierop, W. V. 1976. Digestion procedures for simultaneous automated determination of NH, P, K, Ca, and Mg in plant material. Can. J. Soil Sci. 56:425-432.

Logsdon, G. 1993. Using compost for plant disease control. Biocycle. 34 (10):33-36.

Madejon, E., et. al. 1995. Cotton fertilization with composts of (sugarbeet) vinasse and agricultural residues. Fertil. Res. 42 (1/3):179-182.

Malone R.W., R.C. Warner, and M.E. Byers. 1996. Runoff losses of surface-applied metribuzin as influenced by yard waste compost amendments, no-tillage, and conventional tillage. Bull. Environ. Contam. Toxicol. 57 (4):536-543.

Mandelbaum, R., and Y. Hadar. 1997. Methods for determining pythium suppression in container media. Compost Science & Utilization, 5(2):15-22.

Manios, V.I., and E. Kapetanios. 1992. Effect of town refuse compost as soil amendment on greenhouse tomato crop. Acta. Hortic. 302:193-201.

Manser, A. G. R. and A. A. Keeling. 1996. Processing and Recycling Municipal Waste. CRC Press, Inc.

Marull, J., J. Pinochet, and R. Rodriguezkabana. 1997. Agricultural and municipal compost residues for control of root-knot nematodes in tomato and pepper. Compost Science & Utilization, 5(1):6-15.

Maureen, A., E. Ramirez, and J. L. Garraway. 1982. Plant growth inhibitory activity of extracts of raw and treated pig slurry. J. Sci. Food and Agri. 33:1189-1196.

Maynard, A.A. 1995. Increasing tomato yields with MSW compost. Biocycle. 36 (4): 104-106.

Maynard, D. N. and A. V. Barker. 1969. Studies on the tolerance of plants to ammonium nutrition. Journal of the American Society of Horticultural Science 94:235-239.

McConnell, D.B., M.E. Kane, and A. Shiralipour. 1991. Growth of pickerelweed in municipal solid waste compost and yard trash compost. Proc. Annu. Meet Fla. State Hortic. Soc. 103:165-167.

Melson, E.B., and C.M. Craft. 1992. Suppression of dollar spot on creeping bentgrass and annual bluegrass turf with compost-amended topdressings. Plant Dis. 76 (9):954-958.

Morgan, M. F., 1941. Chemical Soil Diagnosis By the Universal Soil Testing System. Bulletin 450 (A Revision of Bulletin 392). Connecticut Agricultural Experiment Station, New Haven.

Naylor, L. M. 1993. Compost quality assurance for dependable markets. The National Extension Compost Conference. Minneapolis, MN.

Naylor, L. M. 1996. Composting. Biosolids Treatment and Management. Marcel Dekker, Inc.

Nelson, E. B., and C. Craft. 1992. A miniaturized and rapid bioassay for the selection of soil bacteria suppressive to pithium blight of turfgrasses. Phytopathology, 82:206-210.

Nelson, E. B., and C. Craft. 1992. Suppression of dollar spot on creeping bentgrass and annual bluegrass turf with compost-amended topdressing. Plant Disease, 76:954 958.

O'Brien, T. A., and A.V. Barker. 1996. Evaluation of ammonium and soluble salts on Grass sod production in compost. I. Addition of ammonium or nitrate salts. II. Delaying seeding after compost application. Comm. Soil Sci. Plant Anal. 7 (1/2): 57-85.

Olsen, S. R. and L. A. Dean. 1965. Phosphorus. Pp. 035-1049. In: C. A. Black(ed.), Methods of Soil Analysis. Part 2. Agronomy 9. American Society of Agronomy, Madison. WI.

Ozores-Hampton, M. et. al. 1994. Nutrient concentrations, growth, and yield of tomato and squash in municipal soild-waste-amended soil. HortScience. 29 (7): 785-788.

Pagliai, M., G. Guidi, M. La Marca, M. Giachetti, and G. Lucamante. 1981. Effects of sewage ludge and composts on soil porosity and aggregation. J. Environ. Qual. 10: 556-561.

Paino, V., et. al. 1996. Municipal tropical compost: effects on crops and soil properties. Compost sci. util. Emmaus, PA: JG Press.

Peot, C., and D. Thompson. 1996. Compost use in wetland restoration. Biocycle. 37 (1): 65-66.

Raviv, M., Y. Chen and Y. Inbar. 1986. The use of peat and composts as container media. Developments in Plant and Soil Sciences. Martinus Nijhoff.

Rich, J.R., and C.H. Hodge. 1993. Utilization of blue crab scrap compost to suppress Meloidogyne javanica on tomato. Nematropica. 23 (1):1-5.

Richard, T., and M. Chadsay. 1990. Environmental impact of yard waste composting. BioCycle 31(4): 42-46.

Ringer, C. E., P. D. Millner, L. M. Teerlinck and B. W. Lyman. 1997. Suppression of seedling damping-off disease in potting mix containing animal manure composts. Compost Science & Utilization, 5(2):6-14.

Roe, N.E., P.J. Stoffella, and H.H. Bryan. 1993. Municipal solid waste compost suppresses weeds in vegetable crop alleys. HortScience. 28 (12): 1171-1172.

Roper, M. M. 1985. Straw decomposition and nitrogenase activity (C_2H_2-reduction): effects of soil moisture and temperature. Soil Biology & Biochemistry, 17:65-71.

Roper, M. M., and D. M. Halsall. 1986. Use of products of straw decomposition by N fixing (C_2H_2-reducing) populations in bacteria in three soils from wheat growing areas. Australian Journal of Agricultural Research. 37:1-9.

Rosen, C.J., T.R. Halbach, and B.T. Swanson. 1993. Horticultural uses of municipal solid waste composts. HortTechnology. Alexandria, VA: American Society for Horticultural Science. 3 (2): 167-173.

Sann, C. 1995. New uses for compost are being found. Turf Grass Trends. 1.

Schueler, C., H. Vogtmann, and C. Stopes. 1990. The use of composted materials to control plant diseases. Monograph Br. Crop Prot. Counc. 45: 235-238.

Seekins, B. 1996. Field test for compost maturity. Biocycle. 37:72-75.

Serra-Wittling, C., S. Houot, and E. Barriuso. 1996. Modification of soil water retention and biological properties by municipal solid waste compost. Compost Sci. Util. 4 (1): 44-52.

Shiralipour, A., D. B. Mcconnell, and W. H. Smith. 1997. Phytotoxic effects of short chain fatty acid on seed germination and root length of cucumis sativus cv. Poinset. Compost Sci. Util. 5(2):47-52.

Stratton, M. L., A. V. Barker, and J. E. Rechcigl. Compost. Soil Amendments and Environmental Quality. CRC Press, Inc. Lewis Publishers.
Terman, G.L., and D.A. Mays. 1973. Utilization of municipal solid waste compost: Research results at Muscle Shoals, Alabama. Compost Sci. 14: 18-21.

Thomas, R. L., R. W. Sheard, and J.R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus, and potassium analysis of plant materials using a single digestion. Argon. J. 59(5-6):240-243.

Villar, M.C. et. al. 1993. Physical and chemical characterization of four composted urban refuses. Bioresour. technol. Barking, Essex, England: Elservier Applied Science; New York, NY: Elservier Science Publishing Co., 45 (2): 105-113.

Wang, T., T. Yang, and T. Chuang. 1967. Soil phenolic acids as plant growth inhibitors. Soil Sci. 103:239-246.

Werf, P-van-der. 1993. Compost as a partial nutrient source. BioCycle. 34 (2) 79.

Zhang, W., W. A. Dick, and H. A. J. Hoitink. 1996. Compost-induced systemic acquired resistance in cucumber to pythium root rot and anthracnose. Phytopathology, 86(10): 1066-1070.